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UTILIZING IMPROVEMENT SCIENCE TO ADVANCE A STEM IMPROVEMENT
EFFORT: INCREASE THE NUMBER OF UNDERSERVED AND
UNDERREPRESENTED STUDENTS WHO PURSUE A SCIENCE, TECHNOLOGY,
ENGINEERING, AND MATHEMATIC EDUCATION BY
BUILDING COLLECTIVE CAPACITY

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements
for the degree of Doctor of Education

By
David A. Kristofic, Jr.
August 2014

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David A. Kristofic, Jr.

2014

Duquesne University
School of Education
Professional Doctorate in Educational Leadership
Program

Dissertation

Submitted in Partial Fulfillment of the Requirements
For the Degree of Doctor of Education (Ed.D.)

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July 8, 2014

UTILIZING IMPROVEMENT SCIENCE TO ADVANCE A STEM IMPROVEMENT EFFORT:
INCREASE THE NUMBER OF UNDERSERVED AND UNDER REPRESENTED STUDENTS WHO
PURSUE A SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATIC EDUCATION BY
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ABSTRACT

UTILIZING IMPROVEMENT SCIENCE TO ADVANCE A STEM IMPROVEMENT
EFFORT: INCREASE THE NUMBER OF UNDERSERVED AND
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BY

David A. Kristofic, Jr.

July 8, 2014

Dissertation supervised by Dr. Connie M. Moss

The primary purpose of this dissertation in practice is to provide educational leaders with a roadmap for investigating barriers that prevent underserved and underrepresented (USUR) students from entering STEM careers in order to strategically plan their local STEM improvement effort. It offers the educational leader seven guiding principles, along with descriptions and illustrations of Improvement Science tools that include an improvement map, driver diagrams, and examples of one leader's efforts to address his district's unique needs. These Improvement Science tools will enable educational leaders to begin their STEM improvement effort. Improvement Science uses the theory of Profound Knowledge, which combines research with practical knowledge. The methods and approaches can and should be adjusted to local needs and provide a framework to reduce barriers through collaborative and focused efforts.

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Thank you, Dr. Kerr, for serving on my dissertation committee and for providing your ongoing support. Your feedback and guidance helped me when I served as a principal under your leadership and through this process you have taught me how to thoroughly think through educational ideas and how to implement them in practice. You always made yourself available for support and advice. Thank you for your continued interest in my work.

Dr. McCown your vision for the PRODEL program will positively impact educational leaders who work directly with students for years to come. You modeled

how to self- reflect while engaging others within Improvement Science work to create change that will positively impact students within the classroom.

I would like to thank my parents for their positive encouragement as I progressed through every step of my education. And most of all, I want to thank my wife Mindy because without her ongoing support this dissertation in practice would never have been possible. You willingly listened and supported me even when I knew you wanted to talk about something other than STEM education. I love you. Finally, I want to thank my children, Andrew and Grace, because they provided me with the necessary inspiration and perseverance to complete the PRODEL program.

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PREFACE: Lenses of Practice

My Personal Narrative Lens

In our journeys through life, common threads form a fabric of strength, self-efficacy, and commitment. I am a son, a brother, a friend, a father, a community member, a teacher, a coach, and a principal. Being part of each group provides me with multiple experiences and perspectives. There is one common thread, however, that runs through each group: education. Education is the gateway to all opportunities and the foundation for a quality of life.

What do I want for my students, my family, my community members, and my country? I want all of our citizens to have employment options that will allow them to provide for themselves and their families. I want every student to be a global citizen with college and career opportunities locally, regionally, and nationally.

Lens of the Dissertation in Practice

The Carnegie Project for the Education Doctorate (CPED) uses the following criteria to frame the work of a dissertation in practice. The product must:

- a. Identify a researchable, complex problem of practice.
- b. Demonstrate use of rigorous and appropriate methods of inquiry to address the identified complex problem of practice.
- c. Demonstrate potential for positive impact on the identified complex problem of practice.

- d. Demonstrate the integration of both theory and practice to advance professional knowledge and to impact the field.
 - e. Demonstrate the scholarly practitioner's ability to act ethically and with integrity.
 - f. Demonstrate the scholarly practitioner's ability to communicate effectively to an appropriate audience to advance professional knowledge and impact the field.
- (CPED, 2014).

The call for action described and supported in this dissertation in practice focuses on the complex issue of underserved and under-represented students in regard to careers in science, technology, engineering, and mathematics (STEM). It provides a clear analysis of and causal explanation for the institutional barriers that exist in schools. It exercises the integrated lenses of relevant theory and research, and effective educational practice. The fusion of theory, research, and effective practice ensures ethical inquiry to produce sound conclusions and suggested actions that can be pursued with integrity.

Additionally, this dissertation, in practice, contains a roadmap and specific suggestions for educational leaders who intend to pursue removal of STEM barriers in current school cultures in ways that are both meaningful and embedded. The roadmap makes the argument that to truly improve and remove the barriers that exist, educators at all levels of practice must engage in collaborative improvement cycles guided by clearly identified barriers and clearly articulated designs for action.

Chapter 1

Introduction: Significance of the Problem

Chapter 1 introduces and authenticates a persistent and long-standing problem: Students who lack financial and social resources do not have adequate access to educational opportunities that would allow them to pursue careers in science, technology, engineering, and math (STEM). This chapter provides an overview of STEM, explains why STEM education is important, and describes how policy initiatives have failed to improve STEM education and, therefore, access to STEM careers. The chapter concludes with an introduction to the concept of improvement research, the approach that is being used to address the problem.

An Overview of the STEM Landscape

Students who have an interest in STEM careers have a very bright employment future. The U.S Department of Commerce (2011) reports growth in STEM jobs over the past decade was triple that of non-STEM jobs. The fact that STEM workers are less likely to experience joblessness than their non-STEM counterparts plays a key role in sustained growth and stability of the U.S. economy and is critical to helping the U.S. win the future (p. 1).

According to the “Engage to Excel” (2012) report, America must add over one million more STEM professionals over the next decade (p.1). In fact, Hammond (2010) states, STEM professionals fuel the economies of East Asia and Europe, America’s graduates currently rank “near the bottom of countries in math and science achievement”

(p. 3). Even now, America cannot fill available positions in “green” industries or in science and technology due to a lack of qualified candidates (Hammond, 2010, p. 3).

American businesses have a shortage of STEM workers and, as a result must recruit employees from other countries. This problem exists because schools have been unsuccessful in attracting and retaining students within STEM career fields of study. Moreover, American school systems have not successfully reduced the barriers that underserved and underrepresented students (USURS) face. Within the STEM careers USURS have typically been African Americans, Latinos, women, and students who have been raised in poverty. The U.S Census Bureau (2011) reported that women made up 50% of the working population, but only 25% of the STEM workforce, African Americans made up 11% of the workforce but only 6% of the STEM work force, and Latinos represented 15% of the workforce but only 6% of the STEM workforce.

The U.S. Census Bureau projects that by 2050, 45% of the population will be underrepresented minorities, Failure to attract USURS students to the STEM workforce, therefore, will significantly compound the already tenuous nature of the current STEM talent pool. If these trends and conditions prevail, the U.S. will be unable to provide a STEM work force that will allow it to successfully innovate and compete in the global economy. President Barack Obama’s administration recognizes this problem and the 2014 Presidential Budget outlines investments of 3.1 billion dollars of federal funds in STEM programs aimed at “Preparing a 21st Century Workforce” (White House Office of Science and Technology Policy, 2013). If the United States intends to remain globally competitive, the country must significantly increase the number of students who enter the

STEM workforce. Attracting students, specifically underserved and underrepresented students (USURS), is socially responsible and economically necessary.

The Role of STEM Education

Educational reforms and initiatives are a way of life in America's school systems. According to Hess (2013), "It's not reform if it costs more. Reform is finding ways to improve teaching, learning, and schooling with the resources you've got" (p.70). STEM issues in education are not a new area of concern. Past important policies and national reports relative to the impact of reforming STEM education, include but are not limited to *Science: The New Frontier*; *A Nation at Risk*; *No Child Left Behind*; and *Expanding Underrepresented Minority Participation*; *America's Science and Technology Talent at the Crossroads*. These documents are important to examine and review. Understanding historically who has been excluded and who has not will allow leaders to recognize the barriers students face when pursuing a STEM education. Even when students do select to pursue a STEM field of study, they face additional barriers. According to the U.S. Department of Education (2012), these barriers have caused two-thirds of those who have enrolled in STEM courses to leave the STEM field while in college (p. 61).

Barriers faced by USURS are based on multiple factors that include race, gender, and family income levels. In general, the traditional barriers include course offerings, teacher quality, course prerequisites, educator beliefs, parent beliefs, student mindsets, social theories, and teachers' general resistance to change. Therefore, it is critical that educational leaders understand the educational culture and the student barriers that

presently inhibit educational systems in order to develop strategic and intentional ways to decrease barriers for students while providing tools to teachers.

America's Prominence and STEM Education

For America to remain competitive in every aspect of the international market, and highly innovative public education must provide the necessary leadership and enhance the effective teaching of STEM Education. In the attempt to prepare a 21st century workforce, President Obama's 2014 budget has allocated \$3.1 billion of federal funds for STEM education so schools can become successful in attracting students to the STEM career fields (White House Office of Science and Technology Policy, 2013). While America's schools have failed to attract students to STEM fields in general, they have failed miserably in attracting traditionally USURS, such as African Americans, women, Latinos and students who live in conditions of poverty.

United States Department of Commerce (2011) reports STEM positions are expected to grow seventeen percent by 2018 (p. 1) and as a result, American businesses are recruiting employees from foreign countries. Students who enter STEM career fields earn 20% more annually than non-STEM workers. Clearly, educational leaders must become better informed and strategically able to ensure that more USURS enter STEM fields so that America has the STEM workforce it needs.

Past and Present Strategies: Failures and Unintended Consequences

Concerns about America's science and technology workforce have a lengthy history. In July 1945, Vannevar Bush, Director of the Office of Scientific Research and

Development, prepared a report for President Franklin D. Roosevelt titled, *Science: The Endless Frontier*. In it, Bush wrote, “Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress” (p. 2). Over forty years later, in April of 1983, the landmark report, *A Nation at Risk* written by The National Commission on Excellence in Education (1983), included this dire warning: “Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technology innovation is being overtaken by competitors throughout the world” (p. 9). These two statements sound as if they could have been written by President Obama for his 2014 STEM Education Budget Plan. Another recent report about the necessity of increased STEM education was written by the National Academies’ *Rising Above the Gathering Storm* (2007). The report includes recommendations for and a plan to create a STEM workforce by providing incentives to college bound students.

No Child Left Behind (NCLB)

It is impossible for one to consider initiatives to strengthen America’s schools without examining the No Child Left Behind (NCLB) legislation enacted in 2001, especially since NCLB had a significant impact on STEM education. According the US Department of Education Policy (2001) the purpose of NCLB is to “ensure that all children have a fair, equal, and significant opportunity to obtain a high-quality education and reach, at a minimum, proficiency on challenging state academic achievement

standards and state academic assessments” (Public Law 107, Section 1001, 2001, retrieved from <http://www2.ed.gov/policy/elsec/leg/esea02/pg1.html#sec1001>).

NCLB was developed to ensure all students met specific performance levels in math and reading. The goal was to provide a quality education for all students and an economic advantage for the United States in the world economy. School districts were required to reach targeted proficiency standards each year so that year 2014, 100% of the students were expected to be proficient in math and reading. As a result of NCLB and the high stake assessments associated with NCLB, schools and school leaders have felt increased pressure to demonstrate increased students achievement.

According to Hammond (2010),

High-stakes testing has discouraged students and overwhelmed schools have produced higher dropout rates rather than higher standards, leaving the society to contend with a greater number of young people placed into the growing school to the prison pipeline,.... Unfortunately, when using high-stakes contexts, more narrow tests, limited to multiple-choice format, have been found to exert strong pressures to reduce the curriculum to subjects and modes of performance that are tested, and to encourage less focus on complex reasoning and performance... In the process, instructional strategies such as extended writing, research papers, investigations, and computer use are de-emphasized.....Teachers in high-stakes testing states have reported that not only do they no longer teach science or social studies but they do not use computers, because state tests require handwritten answers. (pp. 67-71)

While NCLB did not set out create a negative impact on our nation's students, it inadvertently created additional barriers for STEM education, nevertheless. These high-stake tests affected school instruction in many ways, since they require teachers to cover a multitude of concepts in math and reading, so many that teachers were only able to touch the surface, providing instruction for coverage at the expense of depth of understanding. This type of instruction has not developed students with strong problem-solving or collaboration skills. Further, while many students performed well on the mandated tests, real life applications and applied knowledge opportunities suffered. NCLB has had a negative impact on our nation's attempts to increase the number of students who pursue STEM careers, perhaps because math and engineering fields are so application specific, and many students who were a part of the NCLB era struggle. In fact, "fewer than 40% of the students" who enter STEM degree fields drop out in college, typically they select another area of study where they have experienced educational success (Engage to Excel Report, 2012, p. i).

It is obvious that reports, recommendations, and mandated high-stakes testing will not solve the problem. Rather, this country needs "a national effort to sustain and strengthen our science and engineering workforce [that] must also include a strategy for ensuring that we draw on the minds and talents of all Americans, including minorities who are underrepresented in science and engineering and currently embody an underused resource and a lost opportunity" (The National Academies, 2011, p.20).

National and state governments and local school districts have written STEM like education policies for over 60 years, but the problem of having adequate numbers of

appropriately prepared STEM workers still exists. It should therefore be evident that the adoption of policies or the issuance of national reports has not influenced American's children to pursue STEM courses or to obtain STEM careers. Policies alone will not make an impact. There are no silver bullets when it comes to STEM education. Yeager and Dweck (2012) conclude, "Most often, school reform has attempted to address structural factors such as the size of the school, the quality of the teachers or the length of the school day, or they have attempted to directly teach students skills for studying or learning" (p. 310).

President Obama's budget for STEM education reform includes components that have failed in the past and may suffer the same fate as past failed strategies, national reports or policies. His plan awards grants, creates STEM learning communities, develops STEM master teaching corps, recruits STEM teachers from universities, initiates partnerships between schools and universities, and directs funds towards improving the mathematics achievement between high school and college students (White House Office of Science and Technology Policy, 2013). Americans cannot afford failure within these policies if the country wants to remain and advance as a world leader in a global economy. According to the National Academy of Science (2010), two thirds of the engineers who get PhDs are not Americans (Gathering Storm revisited, 2010, p.4). America needs to create a workforce from within its own borders, and USURS are the key components because they are an untapped American resource.

Within this paper I will share some Improvement Science ideas through applied learning design cycles and implementation experiences as a school principal. Through these shared experiences professional learning will occur which will provide real

classroom teaching experiences and relevant stories to help educational practitioners and school systems to create STEM education improvement. Improving the system through learning opportunities will generate meaningful and substantive change. New policies will not do it alone. Understanding the actors within and around education will allow me to create followers who will attract USUR students towards a STEM education and then a STEM career. Acting as a change agent, one improvement cycle at a time, I will begin to eliminate the barriers faced by USUR students as they undertake STEM education.

The Role of Improvement Research

This dissertation in practice utilizes improvement research techniques and learning design cycles within a school context and directly aims at increasing the number of students who enter STEM career fields, specifically those traditionally USURS. According to the Carnegie Foundation website (2014) improvement research is described as “research that allows us to cull and synthesize the best of what we know from scholarship and practice, rapidly develop and test prospective improvements, deploy what we learn about what works in schools and classrooms, and add to our knowledge to continuously improve the performance of the system”

(<http://www.carnegiefoundation.org/improvement-research/approach>).

Improvement Science techniques, common practice within industries other than education, are just beginning to be utilized in the education field. Improvement Science combines research with a practitioner’s perspective. A core component of Improvement Science is the theory of Profound Knowledge. Langley et al. (2009) describes Profound Knowledge in four related parts: (a) Appreciation for a system; (b) Understanding

variation; (c) Building knowledge; (d) Human side of change. As a part of the theory of Profound Knowledge, improvement cycle ideas build a professional educator's practical knowledge through Plan-Do-Study-Act (PDSA) test cycles (p. 76). The PDSA process is an improvement cycle through which a change is examined in short, interactive cycles.

According to Langley et al. (2009), the process consists of developing a *Plan* to test or implement a theory of action and then to commit to a strategy. The second component is to *Do*. Within the *Do* phase, implementation is attempted and observations are made and documented. The third portion is to *Study* the results and then compare them to the predications to determine if the strategies worked. Finally, *Act* on the findings, and repeat the overall process to build upon the knowledge learned from the tested change (pp. 98-99).

Chapter 2:

Review of the Literature

Chapter 2 examines more closely the nature of the barriers that are at the heart of the problem of equitable access to high quality STEM education and to the career paths that such education can provide. Following a description of some of the issues that prevail in school serving students who live in impoverished conditions, this chapter will address theoretical frames that address the barriers to STEM success. These barriers, which are critical to understand, are often created by perceptions of the underserved and underrepresented (USUR) students bring to learning experiences and foster deficits that cause them to fail. Stereotypes are often damaging in their effects and that is true in the case of barriers to STEM success. Chapter 2 concludes by comparing the kinds of top-down efforts that impose "the solution" on those who work in schools and classrooms with an approach to improvement that insists on working from the ground-up.

Underserved and Underrepresented Students

According to the U.S. Department of Commerce (2011), STEM career fields have a higher earning potential than non-STEM fields and STEM positions are expected to grow by 17 percent by 2018 (p.1). Considering these facts, STEM careers could provide American students with a bright future. Yet, USURS have failed to secure STEM careers due to the significant barriers that limit their interest in and access to STEM careers when compared to students who come from more affluent school communities. Significant portions of the underserved students who are a part of the STEM USUR group are students who live in conditions of poverty that form a barrier for many students.

Hammond (2010) speaks of poverty in terms of inequality, inadequate funding, types of school reform, importance of policy, opportunity gap, how schools are organized, re-segregation, and standards/testing.

Helping teachers and administrators to understand these barriers is the first step to designing an improvement effort among industrialized nations. The United States not only has the highest poverty rates for children, but it also provides fewer social supports for their well-being and fewer resources at school. In 2007, 23% of U.S. children were living in poverty, more than twice the rate of European nations (Hammond, 2010, p.31). Low socioeconomic status affects nearly one quarter of all American students who attend schools. Fewer students who live in conditions of poverty enter STEM fields, mainly because many of the students have not been exposed to the necessary classroom opportunities that would prepare them for a STEM career. Moreover, “schools serving low-income and segregated neighborhoods also provide fewer rigorous college-preparatory and honors courses than schools in more affluent communities. Thus, students who attend segregated and impoverished schools are more likely to drop out of high school; if they do graduate, they are less likely to be successful in college” (Gandara, 2010, p. 62).

Data regarding why schools with high poverty rates underperforms are plentiful. These schools typically have larger class sizes, limited college prep courses, and a limited number of students taking Advanced Placement courses. Additionally, “Schools with high numbers of color commonly offer only the lowest-level introductory computer classes. College preparatory computer science courses and teachers with sufficient backgrounds to teach them are largely missing” (Margolis, Goode, & Bernier, 2011, p.

69). If students are not exposed to the necessary foundation courses, they face a greater likelihood of not entering already elusive STEM career fields. As Green (2011) states, “At the same time the schools are **failing**, the Innovation Economy, fueled by STEM education (Science, Technology, Engineering and Math), is speeding up and producing more jobs that require STEM-educated professionals. At the slothful pace of education reforms, racial minorities trapped in high poverty schools are destined for over-representation in minimum-wage and service sector menial jobs” (p. 3).

Conditions of poverty limit student access to education even in pre-school. In fact, while “65% of children ages three to five (not yet in kindergarten) whose parents earned \$50,000 or more were enrolled in pre-kindergarten...only 44% of children the same age with families incomes below \$15,000 were enrolled..... [and] as more and more middle income children receive preschool education that poor children lack, the gap in cognitive skills, vocabulary, and learning experience the children bring with them to school is further exacerbated” (Hammond, 2010, p.34).

An additional barrier to USURS education exists due to the very structure of funding for Pennsylvania schools through local property taxes. Communities with larger tax bases have more funds to offer for increased educational programs, higher pay for quality teachers, and more extracurricular opportunities for students. Thus, they are able to offer more opportunities to their students than can districts with smaller tax bases. Schools with lower tax bases have larger class sizes, limited exposure to STEM curriculum, and a limited amount of “highly qualified teachers” (Hammond, 2010, p. 44).

Limited teaching experience, however, is not the only teacher factor that limits USURS advancement of USUR to STEM careers. Because students in poverty fewer

opportunities to attend pre-school, often they are behind even before they start school, thus, creating another barrier for USURS. As a result, teacher's perceptions of students are negatively impacted based on how prepared students are when they arrive at school. This creates what Hammond (2010) refers to as a "reverberating cycle of discouragement and failure for less experienced children who soon perceive that they are behind before they even begin" (p. 34).

Gorski (2008) sees this perception of children who come from poverty as a deficit perspective that casts these children as somehow being tarnished, less able, and as "less than" their peers from more affluent communities. This deficit model is grounded in four myths concerning the culture of poverty. First, most people believe that those who live in poor communities live there because they are unmotivated and have a weak work ethic. Second, the public perception is that poor parents do not value education and are not involved in their children's learning. The third commonly held misconception is that those who live in poverty are linguistically deficient. And, finally, it is commonly believed that those who live in conditions of poverty have high levels of drug and alcohol abuse (pp. 33-34).

Through awareness it is possible to help teachers overcome their biases concerning students who live in conditions of poverty. They can do a great deal to help children see that they have choices, but first they must believe that these students actually do have a choice when it comes to their futures. "Being in poverty is rarely about a lack of intelligence or ability. Many individuals stay in poverty because they don't know there is a choice – and if they do know, they have no one to teach them hidden rules or provide resources"(Payne, 1998, p.79).

Theoretical Frameworks

To properly design a strategic framework for action to address the present barriers for USURS in regard to STEM careers, it is important to understand how deficit theory impacts the problem. Defining students by their weaknesses rather than by their strengths casts the students as being the problems and the focus from the barriers that present problems for them. A deficit perspective suggests that poor people are poor because of their own moral and intellectual deficiencies (Gorski, 2008, p. 34). A deficit theorist uses two strategies for propagating this world view: (1) drawing on well-established stereotypes, and (2) ignoring systemic conditions, such as inequitable access to high-quality schooling, that support the cycle of poverty (Gorski, 2008, p. 34). It is important to examine the role of stereotyping plays on STEM education. “Significant numbers of women and underrepresented minorities are missing from the United States STEM workforce today because they were not identified, encouraged or nurtured to pursue STEM studies early on (The Bayer Corporation, 2012, p. 7). Educators in STEM disciplines must therefore, understand the threats that stereotyping pose on the disidentification and discouragement of USURS to pursue STEM related fields.

Steele (1997) defines stereotype threats as the “social psychological threat that arises when one is in a situation or doing something to which a negative stereotype about one’s group applies” (p. 614). Members of the stereotyped group experience greater anxiety when performing tasks at which they are not expected to excel, and, as a result, their performances on the tasks are often not equal to their actual skillset. According to Blascovich (2001), “members of such groups experience stereotype threat when they are in a situation in which other people may view them stereotypically in ways likely to

increase performance pressures (i.e. stress). Research has shown that members of the stereotyped group (African American; Latinos; people of low socioeconomic status; women, in certain domains such as mathematics) perform more poorly on standardized tests, particularly in difficult items, than their non-stereotype counterparts" (p. 225).

For example, a common stereotype is that boys are better than girls at math and science. When girls hear from their parents and teachers year after year, it begins to have an impact. Findings from a research study focused on the stereotype threat to women's achievement in high-level math courses tell us that "expectancies set early in childhood by parents may lay the foundation for later underperformance, interest, and participation during adolescence.... When negative stereotypes are activated and left unchecked, they trigger a number of disruptive psychological processes that undermine test performance" (Good, 2008, p. 18).

A second example of stereotype threat is known as disidentification. According to Aronson (2001), this threat is characterized by psychological disengagements from achievement hypothesized to help students cope with stereotype threat and underperformance in a given domain (p. 114). Many researchers have noted that to promote and maintain self-esteem, students tend to identify with—that is, to base their self-esteem upon-domains in which they excel (e.g., Eccles and Wigfield, 1995; Harter 1990). To sustain self-esteem, one needs either to succeed in a domain, if one can, or to disidentify from the domain, if one cannot.

Teachers must become aware of stereotype threat and disidentification so that work to combat these stereotyping threats may be implemented within their classroom practice. Such efforts are critical since teachers who are unaware of stereotyping create

classroom cultures that often influence students to devalue certain courses or disciplines. According to Arosen (2001), devaluing can be observed when, for example, “a student proclaims that “math is for nerds” in response to receiving a poor grade in math class ... Over time, chronic disengagement of this sort may lead a student to disidentify fully from mathematics”(p.114). Clearly, when students are repeatedly unsuccessful in a subject, they begin to devalue the subject. This is especially lethal for female students. Good (2008) explains that the “effects of stereotypes on professional identity have roots early in schooling, for it has been found that stereotypes can undermine sense of belonging for girls in math as early as middle school. This has important consequences for girls’ identity as future mathematicians and scientists because it is precisely the middle school years when girls’ confidence in and liking of mathematics begins to wane" (p. 27).

Besides getting female students to experience success in math, many teachers inspire students to believe in themselves. According to McIntyre et al. (2005), educational leaders can “use a personally relevant woman who excels at math to counter-argue the stereotype” (p.118). When studying the impacts of a strong role model on alleviating women’s mathematic stereotype threat, McIntyre et al. (2005) found that when female test takers read three biographies of three successful women prior to taking a math test, they performed equally as well as men on the exam. “The effect of role models on performance under stereotype threat might be similar to the effect of what Latane (1981) calls “pseudo groups” (imagined others who are not physically present) on reducing the pressure that a situation exerts on an individual. The larger the number of imagined others who share the burden, the less the pressure on any one target person (Latane, Williams, and Harkins, 1979); perhaps because of perceived diffusion of

responsibility or freedom from making a fool of oneself (Darley & Latane, 1968), which can occur even when the other people are only imagined” (McIntyre et al., 2005, p.124).

In fact, successful role models can have a cumulative effect over time, meaning that when women are exposed to quality role models and see them perform well, they are more likely to become role models themselves (McIntyre et al., 2005, p. 126).

Fixed Mindsets

All students, whether they are USURS or not, can achieve at similar levels when teachers understand USUR student barriers to STEM, and when students are given equal access to a rigorous STEM education. Thus, understanding student and school barriers to STEM is a key component of improving USUR students’ access to a STEM education. That means that educational leaders must work to understand the power of student and teacher mindsets as they relate to learning. Carol Dweck (2006), a known expert on human cognition, has identified two mindsets—a fixed mindset, and a growth mindset. According to Dweck, "the fixed mindset creates an urgency to prove yourself over and over. If you have only a certain amount of intelligence, a certain personality, and a certain moral character—well, then you’d better prove that you have a healthy dose of them. It simply wouldn’t do to look or feel deficient in these most basic characteristics” (p. 6). People with a fixed mindset perspective strongly believe that IQ scores are the ultimate barometer of a student’s ability that students are limited by their IQ scores that are fixed and not subject to change. The teacher, therefore, has no power to increase a student’s intelligence or achievement.

In direct opposition, those who have a growth mindset believe that a person's "basic qualities are things you can cultivate through your efforts. Although people may differ in every which way—in their initial talents and aptitudes, interest, or temperaments—everyone can change and grow through application and experience" (Dweck, 2007, p. 7). If teachers approached all students with a growth mindset, therefore, they could create a healthy environment where USURS could develop the STEM skills comparable to what their classroom peers have developed.

Accepting such a syllogism, educational leaders, therefore, must promote learning cultures that foster developing growth mindset in teachers. They also must take steps to assess the culture of their schools to determine if staff members regard students through the lens of a fixed or a growth mindset, since the preconceived mindset of a teacher impacts the teaching strategies that teacher employs with USURS. Since teaching strategies can impede students from developing an interest in STEM it is critical that schools provide ongoing professional development experiences that will enable teachers to see the value in thinking from the growth mindset.

Stereotype Threats and Implicit Bias

A strategic professional development plan should inform educators about stereotype threats and implicit bias. Stereotype threats have a significant impact on minorities, female, and poverty students' interest levels in relation to STEM education. For example, female students with equal ability levels in mathematics have not performed on par with boys when taking high stake tests. Hill (2010) views stereotype threats as a possible explanation for fewer females expressing interest in STEM fields

because they do not want to be judged as not being effective. The idea that these biases are implicit, hidden, or unconscious exacerbates their impact. “These unconscious beliefs or implicit bias may be more powerful than explicitly held beliefs and values simply because we are not aware of them” (Hill, 2010, p.74).

These implicit biases can come from teachers, parents, and from the overall culture. An important first step to eliminating this problem is to educate society on the impact of implicit biases and stereotype threats on USURS and their interest levels in STEM careers. Such action would bring about a more inclusive and nurturing STEM culture in the schools, thus creating a culture which would produce graduates who seek out STEM careers even when coming from underserved or underrepresented groups. It would address the root of the USURSs’ STEM problem and build a new culture from the ground up, by creating a new generation of educationally prepared STEM students.

Finding a Method to Create Improvement

To fully understand the context around suggested improvement efforts highlighted in this report as it relates to increasing the number of USURS entering the STEM career fields, one must understand the problem and why it continues to exist even though resources have been directed at this topic for decades. Many research-based reports have been issued to the White House, offering STEM recommendations aimed at increasing interest in STEM education. Most recently, the 2012 National Academies report, *Engaged to Excel*, suggested a wide variety of action points for STEM education. While there is never a shortage of good ideas and recommendations for K-12 education, these reports seem to have had little or no impact in affecting what is being taught within

the schools. Obviously, there is a disconnect between educational researchers and practitioners. If improvement is going to actually happen, the educational leader within the school must lead the change or the change efforts will fail. Without a sustained endeavor, the suggested new initiatives are not effective. Developing an understanding of the school building and school district's needs while developing professional working relationships with educators is crucial for continuous school improvement. Displaying a sincere interest in the school, teachers, and the overall system is the first priority and must be evident to all stakeholders in the school and in the district if improvement efforts are going to be successful. Simply put, "the quality of an education system cannot exceed the quality of its teachers" (Barber and Morshed as cited in Dufour & Marzano, 2011, p.16).

Local, state and federal governments place many demands upon teachers and principals each school year from local, state and federal governments. In the Pennsylvania school systems these demands include Keystone Exams, School Performance Profiles (SPP), Pennsylvania Core Curriculum and Act 82. Act 82 is a new clinical teacher observation system designed to reward Pennsylvania teachers for professional growth and improvement a new superintendent, assistant superintendent, and/or principal, frequently will want teachers to make modifications. Each change initiative is touted as being a solution to a problem but teachers become all too familiar with the process of enacting new strategies only to see them fail to solve a particular problem. NCLB is a perfect example of a change that did not live up to its promise of 100% student proficiency. Educators are simply tired of repeatedly making changes year

after year, but seeing no improvement. Many schools and districts are living with initiative fatigue as a result.

The approach by Bryk, Gomez, and Grunow (2010) suggests that building networked communities into the educational landscape can favorably impact the success of a change initiative. In addition, the work of Langley et al. (2009) that resulted in *The Improvement Guide* is being embraced for its potential to tailor improvements to the needs and strengths of particular schools and districts. Together, these resources, both of which are based on Improvement Science, hold promise for educational leaders faced with implementing an improvement effort.

Improvement research does not focus on the solution, but rather on the problem. It utilizes “practical theory” as a framework “that practitioners can see as useful in guiding their work” (Yeager, 2013, p. 17). For example, the Pennsylvania Department of Education’s mandated Act 82 could provide the framework for a great change opportunity for teachers to showcase their skills while reflecting on their professional actions taken to address issues of USURS and STEM.

Pennsylvania’s Act 82 requires teachers to focus on their students’ academic growth while demonstrating their professional growth. Improvement Science ideas can be easily embedded within this mandatory change. If effective, teachers will demonstrate how they have or intend to improve their professional practices within the school and with their students. This would represent a cultural change within the educational system that could first lead to teacher improvement and eventually to school-wide improvement. Dufour and Marzano (2011) note that “schools have lacked the collective capacity to

promote learning for all students in the existing structures and cultures of the systems in which they work” (p. 15).

Pennsylvania’s past structure for a teacher observation system did not reward growth. The new model will provide leaders with the opportunity to talk with teachers directly about improvement. Having these long overdue conversations is a crucial step but when the conversation focuses on school improvement, it must include teacher improvement.

According to Dufour & Marzano,

That is the only way to improve schools, unless you mean painting the building and fixing the floor. But that’s not the school: it is the shell. The school is people, so when we talk about excellence or improvement or progress, we are really talking about the people who make up the building” (as cited Boyer, 2011, p.15)

Effective leaders can use the new educator evaluation model to create opportunities for educators to improve their professional practice. And while Pennsylvania’s teacher observation initiative is no different than many of the other changes handed down from the government, an educational leader could use the Improvement Science framework (Langley et al., 2009) to encourage teachers to change their perspectives and to support them in the process.

This framework has five essential points that help the educational leader to better communicate a change initiative. First, the leader must describe the advantage of the elements of the suggested change over previous changes and the status quo. Specifically,

the leader must answer the question, “What is in it for me?” for each member of the school community. Second, the leader must find ways to align and integrate elements of the change with the current culture and values of the system. This helps the stakeholder build on familiar concepts. Third, the leader must explain the change in terms that are easy to understand and to minimize complexity and jargon. Fourth, it is essential for the leader to provide their colleagues with time and support to implement and to test the new change. And finally, leaders must arrange for people to observe the success of this change from others. Essentially, “commitment to change is built through sharing of information. Leaders understand we have bad systems, not bad people.” (Langley et al., 2009, p. 85)

Educational leaders know that the strength of any improvement begins with teachers’ educational knowledge. Therefore, the first step towards USURS STEM improvement must begin with educators because they are the key component of the overall school environment. Dufour and Marzano (2011) believe improvement rests on building collective capacity, beginning with teachers. If teachers improve, so then will the students, the building, and then the district.

According to Dufour and Marzano (2011),

A commitment to building collective capacity requires a school environment in which professional learning is:

- Ongoing and sustained rather than episodic
- Job-embedded rather than separate from the work and external to the school

- Specifically aligned with school and district goals rather than the random pursuit of trendy topics
- Focused on improved results rather than projects and activities
- Viewed as a collective and collaborative endeavor rather than an individual activity (2011, p. 20)

Administrators must create the capacity for continuous improvement as an integral part of the new Pennsylvania Teacher Effectiveness Evaluation Model, making it embedded and not just another top-down mandated change initiative. The factors that facilitate professionals to change must be understood for any improvement efforts to have a meaningful impact.

The Promise of Improvement Science

A key component of Improvement Science is harnessing the wisdom of the crowd. As one looks to improve STEM education for USUR, the focus will be the framework established by the Carnegie Foundation for the Advancement of Teaching, which has a new approach to improving educational practice. The Carnegie Foundation wants to create opportunities for researchers and practitioners to work cooperatively to create actual solutions within practice, according to Bryk (2010). This type of research is considered Design-Based Research (DBR). Anderson (2012) states, “DBR is a methodology designed by and for educators that seeks to increase the impact, transfer, and translation of educational research into practice. In addition, it stresses the need for theory building and the development of design principles that guide, inform, and improve both practice and research in educational contexts” (p. 16).

The Carnegie Statway Network approach stresses the importance of creating a partnership between schools, academy, and the community (SAC) for supporting an improvement initiative. Among the SAC entities, there will be opportunities for the partners to learn through doing with an environment referred to as the Networked Improvement Community. Through this type of designed based research (DBR), “the creation begins with an accurate assessment of the local context; is informed by relevant literature, theory, and practice from other contexts; and is designed specifically to overcome some problem or create an improvement in local practice” (Anderson, 2012, p.16). Bryk (2009) states, “Knowing that a program can work is not good enough; we need to know *how to make it work* reliably over many diverse contexts and situations. (p. 598)

Based upon my professional background and broad-based experiences, I believe that the Theory of Profound Knowledge will effectively connect the educational researcher and the practitioner. Langley et al. (2009) stated,

Deming defined the System of Profound Knowledge as the interplay of the theories of systems, variation, knowledge, and psychology” (p.75)....The ability to make improvements is enhanced by combining subject matter knowledge and profound knowledge in creative ways. Deming describes profound knowledge in four parts, all related to each other: 1) Appreciation for a system, 2) Human side of change, 3) Building knowledge, and 4) Understanding (p. 76)

In the vein of improvement, which addresses educational problems, Bryk (2010) suggests that the PDSA cycle is a promising tool to structure inquiry because it rapidly

tests change, can be revised quickly, and allows for retesting quickly. Bryk uses the PDSA cycle as defined by Langley et al. (2009).

To be considered a PDSA Cycle, four aspects of the activity should be easily identifiable:

1. **Plan:** the learning opportunity, test, or implementation is planned and included:
 - Questions to be answered
 - Predictions of the answers to the questions
 - Plan for collection of data to answer the questions
2. **Do:** the plan was attempted. Observations are made and recorded, including those things that were not part of the plan.
3. **Study:** time was set aside to compare the data with the predications and study the results.
4. **Act:** action was rationally based on what was learned.

The PDSA Cycle is a vehicle for learning and action. The three most common ways for using the cycle as a part of an improvement effort are:

1. To build knowledge to help answer any one of the questions
2. To test a change
3. To implement a change” (2009, pp. 98-99)

Park (2013) clarifies PDSA act cycles further, as follows:

- **Testing changes:** The PDSA cycle is shorthand for testing a change in a real work setting by planning it, trying it, observing the results, and acting on what is learned.

- **Implementing changes:** After testing change on a small scale, learning from each test and refining the change through several PDAS cycles, the team may implement the change on a broader scale.
- **Spreading changes:** After several successful implementations of a change/package of changes, the team can spread these to other parts of the organization or to other organizations (p. 30).

Chapter 3

Methods and Designs for Learning

Chapter 3 shares one school's effort to improve STEM education. Three specific learning design cycles were attempted to reduce student barriers to a STEM education. Each of the three learning opportunities helped the educational leader to first to understand and then to analyze the design to determine if the learning methods reached the improvement aim. Chapter 3 concludes with a review of what was learned through the improvement research infrastructure to learn the impact of change and the ideas that were tested in practice with students and teachers to determine if the change reduced USUR student barriers to STEM education

Designs for Learning:

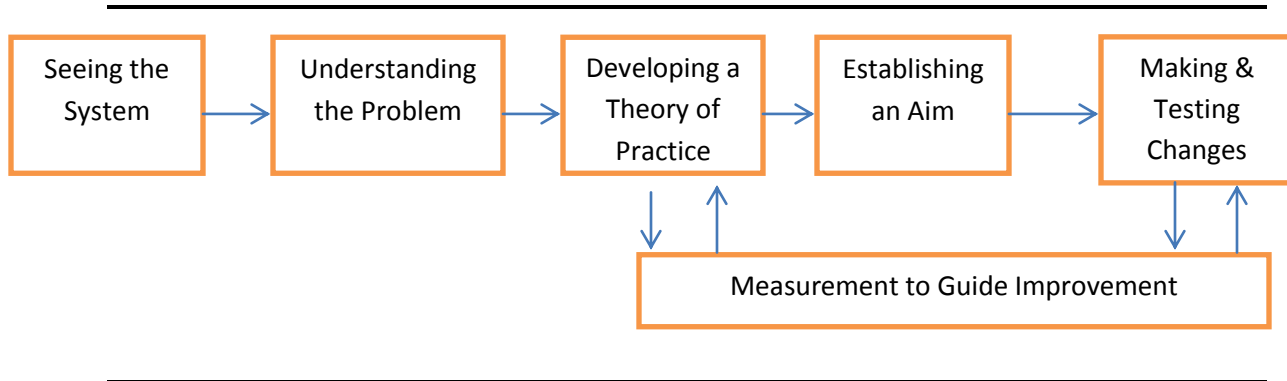
When creating a design for learning—the Plan, Do, Study, Act (PDSA) cycle—for a teaching faculty, the educational leader should reference an improvement tool developed by Park and Takahashi (2013), in the creation of a design for learning. For example, a 90-day PDSA cycle includes six elements: 1) Intent statement, 2) Aim Statement, 3) Audience, 4) Deliverable, 5) Team leader and support members and 6) Key resources and experts (p. 9-10).

Past efforts to increase the number of American students entering STEM fields have not been successful, especially for USUR students. A recent report issued by The National Academy of Sciences (2011) stated,

In spite of the numerous reports and policy and reform initiatives targeting curriculum and educational standards, assessments, and teacher preparation, today the nation is faced with the same issues (p.54) Previous efforts have produced mixed results for the general populace and have had limited effectiveness in bridging the achievement gap for underrepresented minorities, the fastest growing segment of the U.S. population... There are systemic failures in the implementation of federal, state, and local policies designed to provide equity and excellence in K-12 education, and these failures weaken our foundation for future prosperity (pp. 55-56).

In Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads (2011) has some promising STEM solution ideas and recommendations. Unfortunately, this report will have the same outcome as reports issued prior to it if school-specific action is not taken at local levels. Use of Improvement Science as a method to improve this problem will provide local level learning for both the student and the teacher. The Carnegie Foundation for the Advancement of Teaching illustrates a scope and sequence guide for improvement (Carnegie Foundation Summit, 2014).

Figure 3.1 – Scope and Sequence Guide for Improvement



Langley et al. (2009) stresses seeing the system and the human side of change as important concepts that an educational leader must consider before creating a PDSA cycle (Design for Learning). The Taylor Francis (2012) group contends that change will happen only when “learners must experience dissatisfaction with an existing conception... New conception must be plausible to the learner and preferably consistent with accepted theories” (p. 102).

School districts launch many new initiatives each year, but before the initiative gathers traction, it quickly fades because a new one is suddenly proposed. Before developing a formal STEM improvement plan for our district Bryk recommended these three specific action points at a 2012, CPED conference.

1. See a system and improve it
2. Rapid small chunks of change
3. Learn fast, fail fast, improve fast

Dr. Bryk the president of the Carnegie Foundation for the Advancement of Teaching suggested (2012, CPED conference) educational leaders who are trying to create

improvement within their organization to ask these four questions prior to developing an improvement plan:

1. How do we understand the problem?
2. What are we trying to accomplish?
3. What changes might we induce?
4. Are changes improvements?

These recommendations will guide the development, the learning designs (action research), and the approach to the planning of the plan. Before testing any designs in practice, it was also important to learn about promising practices others have attempted and which have the potential to positively impact USURSSs' involvement within STEM. The National Academies of Sciences (2011) recommended multiple promising practices. They concluded,

Lack of knowledge and familiarity on the part of UR minorities in terms of what constitutes careers in STEM may contribute to their limited presence in these fields (Hill, Pettus, and Hedin 1990). Knowledge about STEM career and exposure to scientists and engineers have been found to increase minority student's commitment to a STEM major degree aspirations, and commitment to a STEM career (Good Halpin and Halpin 2001; Rolle 1977; Wyer 2001) (p. 99).

Additional practices resulting in positive impacts were developed through an executive summary issued by Bayer Fact Surveys from 1995 to 2011. Four of their universal beliefs provide further validity as to why it is important to interact directly with STEM professionals. The Bayer report, *STEM education, Science Literacy and the Innovation Workforce in America*: (2012) concludes,

1. Students and teachers benefit from having direct access to scientists and engineers on a regular basis in the classroom.
2. America's future STEM leadership is dependent on the country's ability to recruit and retain more women, African-Americans, Hispanics and American Indians (underrepresented minorities) in STEM fields.
3. Improving education for all students—especially girls and underrepresented minorities (URM's)—should be a national priority and begin at the earliest possible elementary school level since that's where the STEM workforce truly begins.
4. A hands-on, minds-on approach to science education is the best way for students to learn science and build crucial science literacy skills, such as critical thinking, problem solving and the ability to work in teams (p. 1).

Having direct access to STEM professionals is also supported by a study from The Royal Society. Cummins (2004) concludes, "A survey of over 1,000 scientists and engineers in 2004 showed that just over half (52%) had been influenced in their choice of career by a visit to a scientist's or engineer's place of work, and nearly a quarter (23%) had been influenced by a scientist or engineer visiting their school" (p. 14).

Testing a Change

Before developing and implementing any change ideas, Langley et al. (2009) recommend testing the ideas as practice before implementation. He sees Improvement Science techniques as a way to test change, make predictions, and learn to build upon the

knowledge to decide upon appropriate actions for a system. Langley et al. suggest that testing, failing, and learning from mistakes must occur prior to implementation (p. 139).

Through action research in practice, learning design cycles will be used to share information and to make predictions. These designs for learning will provide the educational leader with specific information from practice to develop new predictions and/or alternatives. Even if the learning designs are not successful, learning will occur and will impact future designs for learning. The aim of these learning design experiments is to learn from implemented actions in context and to share thinking about what went well and what failed. After each cycle of learning, adjustments should be made and tried again quickly. Improvement Science suggests using small pockets to test possible solution ideas and does not require the entire system to implement it.

Langley et al. (2009) suggests small-scale changes are critical because change is not perfect, through the change you will learn and improve. Designs for learning will provide the educational leader with specific information that the leader will use to plan a system-wide STEM improvement effort designed for a local context. Through this improvement effort, three specific STEM learning design experiments were trialed over a two year period. During faculty meetings and in-service days the staff was presented with STEM information with hopes of engaging teachers to volunteer to work with each of the three learning design cycles.

The Principal's Role Through the Learning Design Cycles

Each learning design aim was to reduce USURSS' barriers to STEM. Following the initial planning stages of each learning design, the principal's main role was to recruit

followers to each learning design experiment. After engaging others to participate, I then observed each learning design to determine what was, or what was not learned through each learning design. I will share how I attempted to attract followers and what was garnered from each learning design.

Learning Design Cycle One

As I was planning these learning design cycles for my students and teachers, I was presented with a unique opportunity to speak to 30 STEM professionals for five minutes at a school district planned STEM meeting. This was my targeted audience for the first learning design. The aim was to attract STEM professionals to work with our school as well as to present USUR students with local STEM role models. Through a comprehensive review of literature, it was found that presenting students with STEM role models helped to reduce barriers to a STEM education.

As I reflected on how to engage STEM professionals to give up their time to speak to students, I thought it would be important to provide them with a brief overview of America's STEM problem. During the presentation, I used my personal narrative along, with my school leadership experiences to tell a story about why my students needed STEM professionals to be career role models or career storytellers. I offered several examples of the impact of the poor role models that students see each day in the media, and shared my personal narrative regarding the lack of STEM influences in my life. Last, I asked the STEM professionals for their help because our students needed them to be career role models or career storytellers.

The responses to my invitation to become career role models or career storytellers were excellent. During the 2012-13 school year, my school had 23 career role models present to our students. Before the presentations we spent a little time with each presenter, offering tips and suggestions that would help engage middle school students. We asked our career role models and storytellers to share specific information about their career positions. Such information included what types of education needed, why they selected their career, what an actual day looked like for the professional engineer was not doing math problems all day and what other types of skills were important. Many of the presenters engaged the students within an interactive presentation or lesson.

These STEM professionals have been and continue to be invaluable influence to our students and they can be powerful partners our school system. While it certainly will be difficult to measure the generative impacts (increasing the number of students who enter STEM career field) of this design model since the students are only in 7th and 8th grades, it is hopeful that continued and frequent exposure will transfer into long-term interest. I had the opportunity to see the students' reactions and hear the students' conversations in the classrooms, hallways, and in the cafeteria, and there is no question that their interests were positively impacted.

The Cummings Study (2004) states that 23% of scientists and engineer professionals were influenced by a scientist or engineer visiting their school (p. 14). Providing 730 students with the opportunity to hear four or five STEM professionals has the potential to significantly impact our students' career choices. Implementing this "zero-cost" approach is a design for learning that can leverage change for our students.

Of the twenty or so career role models who presented at my school, seven were women and/or minorities. Having USUR role models is another extremely valuable aspect of a learning design cycle. Within the Royal Society Study, Cummins concludes, “Role models can play a major part in challenging the stereotype of science and engineering being unsuitable for women (2004, p. 3). A study completed by the Bayer Corporation (2012) reports that underrepresented minorities and women face the following barriers:

1. Lack of STEM role models is a barrier facing both their URM (17%) and Female STEM (13%) undergraduates
2. Overcoming the stereotype of white male dominance
3. The numbers are always small and they can feel isolated
4. Stereotypes exist that say STEM isn’t for girls/URMs
5. Lack of confidence/Self-doubt (p.19)

During the 2013-14 school year, I implemented the second learning design cycle of career role models and career storytellers. Through this cycle I targeted parents who were STEM professionals within the school community. During the fall of 2013’s open house, I provided the parents with a text-to-movie video presentation which explained our need for career role models or career storytellers and they too, volunteered to speak to our students.

During engineering week, a local business learned about our career role model efforts and sent 10 engineers to our school to share their professional experiences. Throughout the presentations, the engineers explained how important 21st century skills

were to the students. Team building and collaboration skills were the main focuses of their presentations. The classroom activities concluded with the students building a tower out of spaghetti noodles and gum drops. This activity required that they employed collaborative techniques develop a building plan, and the groups who were most successful in the execution of the assigned task were the groups who communicated well.

Through this learning design cycle, the engineers stressed the importance of teamwork and communication as essential skills. After the presentation, the engineers asked each teacher to incorporate as many opportunities for their students to build upon their teamwork and communication skills, even when not engaged in STEM activities.

When using Improvement Science techniques, Langley et al. states, “Be ready to learn from unexpected results of the test, as well as the planned ones” (2009, p. 18). As a result of this learning design, our school has established a positive working relationship with Allegheny Land Trust (ALT). ALT traditionally acquires land that needs cleaned up or has been abandoned. Initially, a representative from ALT made a single class presentation to 30 students explaining the process of the acquisition of unwanted land to make it usable for local communities. At the conclusion of the presentation, the presenter was pleased with the students’ responses.

With a little brainstorming between the teacher and the ALT presenter, they developed an assembly for our 8th grade students where they were provided with a brief history of the locally acquired land and its regional importance. ALT then asked the students for their help in creating ideas about how the land could be utilized once all of the old greenhouses and debris were removed from the property. After the presentation, our students participated in breakout sessions where they were given a detailed map of

the property. The students were charged with selecting the best locations for a solar farm and walking trail. They were then required to state the reasons why they selected the positions for the solar farm and walking trail. Student engagement was very high because the presenters used active learning strategies. The students worked with actual maps of the property. ALT stated the most feasible ideas would be utilized.

Learning Design Cycle One Results

The first learning design cycle generated a new way of thinking and has provided our students and school with a unique opportunity to experience actual STEM opportunities from STEM professionals. Overall student feedback was positive, and it was evident through their responses that they developed a greater understanding of the STEM careers presented to them. The overall impact of the career role model design experiment is not immediately known as our students are in middle school. I will monitor students' high school course selections to determine if a greater number of students eventually register for STEM courses.

Learning Design Cycle Two

The second learning design cycle was structured to impact both the students and the teachers. In January 2013, I secured Pittsburgh Pirates Charities grant that enabled two mathematics teachers to receive professional development on how to implement a Fantasy Baseball game. This program was designed to spark interest and excitement around a mathematical game for students who have typically struggled with mathematical concepts. Through the game, students developed the following math skills: proportion,

ratios, algebraic thinking, geometry (real world math problems) as well as statistics and probability while being actively engaged in the process. Besides the math skills, the students had hands-on experience with 21st century skills of innovation, creativity, critical thinking, communication, and teamwork skills.

Forty 7th grade students registered to play this instructional game once a week beginning in March and it concluded with a Fantasy Baseball World Series game at PNC Park in May 2013. A large number of these students had scored at the basic or below basic levels on the Pennsylvania State System Assessment (PSSA) in mathematics. Often times low performing math students have not found math class motivational, as they have not experienced math with active learning techniques, and so, the goal was to create excitement around mathematical concepts.

According to their responses, the students found each Friday Fantasy Baseball experience to be enjoyable and motivational. They willingly and excitedly participated within the classroom activities each week and towards the end of the season, the students were asked to play the game multiple times per week. Needless to say, our math teachers willingly agreed. After holding a math tournament on the last Friday of the season, the top four teams had the opportunity to go to PNC Park to participate in World Series of Fantasy Baseball against other students. This experience was motivational for our students and it was a pleasure to observe them enthusiastically participate in a mathematical activity.

The two teachers who participated in the fantasy math program were very focused on preparing their students for state assessments. My hope was to introduce them to active learning strategies that they traditionally did not employ. These teachers are capable of

utilizing these types of strategies, but they typically rely on “drill and kill” strategies that enable them to cover as many tested concepts as possible. At first, they were not willing or were afraid to spend time playing a game. The aim was to use their participation in the Fantasy Baseball experience to increase their understanding that engaging struggling students through this active learning strategy is a worthy use of class time.

When it was time to plan for the second cycle of Fantasy Baseball, two additional teachers inquired about the program based on the enthusiasm and unsolicited interest of students who inquired if they were going to have the opportunity to play. As a result, both teachers participated in the Fantasy Baseball teacher training, following which, they met with previous two teachers who participated within the program during the first year.

Learning Design Cycle Two Results

The teachers who participated in the first Fantasy Baseball learning design experiment were provided with an opportunity to meet with the newly trained teachers. Using Improvement Science techniques, the first group provided implementation tips and suggestions, and they shared teaching techniques that they found to be most effective.

Overall, the goal of the first Fantasy Baseball design for learning was effective, and the students had a positive math experience. They shared their positive experiences with their next year’s teachers, and as a result, the teachers inquired and then volunteered to attend the necessary training so they also could implement the program.

A secondary aim was for the teachers to take the initiative to develop more hands-on opportunities for their students immediately after the Fantasy Baseball learning design cycle. Unfortunately, the instructional strategies did not immediately impact the teaching

style of the teachers during the first year. There was evidence, however, that additional active learning strategies were used during the second year.

During the second learning cycle, I utilized the new state Teacher Effectiveness Evaluation Model to my advantage. The teachers were asked to reflect on their teaching and write professional goals to develop and utilize more active learning strategies. Although large instructional delivery changes were not made, some instructional strategy progress was evident.

Learning Design Cycle Three

The third learning design cycle was the implementation of a Professional Learning Community. According to Dufour and Marzano,

The best strategy for improving schools and districts is developing the collective capacity of educators to function as members of a professional learning community (PLC) – a concept based on the premise that if students are to learn at higher levels, processes must be in place to ensure the ongoing, job-embedded learning of the adults who serve them. (2011, p. 21)

For my first PLC, I selected a book written by Roger Shank, *Teaching Minds*, to launch our building PLC process. This book provided a unique perspective about teaching and learning to challenge teachers' instructional practices while providing insights from Shank's perspective. The presentation was created specifically for the teachers and staff within my school system. To attract teachers to engage within this

PLC, I excerpted two passages from Shank's (2011) book during an in-service training.

The first passage related to making math meaningful to students:

Why don't kids like school? Because we teach them knowledge that they know they will not need. How do they know this? They know that their parents don't know this stuff – that is how. Many kids don't like math much and it is clear why. They find it boring and irrelevant to anything they care about doing. If we think math is so important, why not teach it within a meaningful context, where it actually can be used? There is plenty of evidence that shows that teaching math within a real and meaningful context works a whole lot better than shoving it down their throats and following that with a multiple choice test. (p. 80)

The second passage was:

What we say is that we must teach math and science better in high school, when what we mean is that it would be nice to have some more American-born scientists. Do we really believe that the reason that there are so many foreign born applicants to U.S. graduate programs is that they teach math and science better in other countries? China and India provide most of the applicants. They also have most of the world's people. Many of those people will do anything to live in the United States. So, they cram math down their throat, knowing that it is a ticket to America. Very few of these applicants come from Germany, Sweden, France or Italy. Is this because they teach math badly in those countries, or is it because those people aren't desperate to move to the United States? U.S. students are not desperate to move to the United States, so when you suggest to them that they numb themselves with formulas and

equations, they refuse to do so. The right answer would be to make math and science actually interesting. (Shank, 2011, pgs. 82-83)

By selecting Shank's book, I wanted to introduce my teachers, specifically STEM teachers, another perspective that would challenge their traditional thinking as it related to their use of instructional strategies. Through a discussion of Shank's suggestions of improved instructional approaches, teachers would be able to engage all types of learners through learning by doing, an active teaching strategy which is a focal point of this book. During this time, our district had recently adopted the Project Lead the Way (PLTW) curriculum for our middle school students. Through the PLTW course, our students created projects that required 21st century skills, specifically innovation and collaboration. These are the 21st century skills our school district has been discussing through the adoption of the district's strategic plan. The aim for participating within this PLC was to provide teachers with opportunities to think about process-based education, real-life learning projects, and knowledge-based education vs. process-based education ideas.

Learning Design Cycle Three Results

Almost a dozen teachers participated in a bi-monthly PLC meeting. Teachers' responses to the book varied, sparking spirited discussions. The book challenges many of the status quo practices in education and, depending upon an educator's perspective or willingness to challenge him or herself, each educator brought a different interpretation to Shank's ideas. The goal was to build teachers' knowledge, a critical step of this learning design. Unfortunately, the book challenged too many educators' core beliefs at once and

many teachers expressed that they did not have the resources to implement many of the learning-by-doing ideas. This book was not presented as a solution idea, but rather as an alternative method to engage students within STEM career fields, with the goal being for teachers to try at least one learning by doing unit.

Another tenet of Improvement Science is that the educational leaders must understand how to implement a change. Implementing this idea of change idea during the last nine weeks of the school year did not demonstrate adequate planning on my part, for it did not provide the teachers with enough time to make a change within the current school year. I learned painfully well that it is imperative to enact rapid, small chunks of change. Fortunately, for me, another core tenet of Improvement Science (Bryk, 2013) is to “learn fast, fail fast, and improve quickly” (retrieved from <http://www.carnegiefoundation.org>). Even though this PLC was not as productive as I intended, I did learn from this learning design and I am confident that with adjustments, this same book could provide a significant role within a STEM PLC if it were presented differently.

Learning Design Experiment Conclusion

I selected three learning experiments, Career Role Models, Fantasy Baseball, and the Teaching Minds PLC, because each one of these ideas could minimize the barriers faced by USUR students hoping to pursue a STEM education or a STEM career. The design experiments were attempted to raise awareness for both the students and the teachers. These designs were not expected to solve our school's STEM problem. The Theory of Profound Knowledge (Langley et al., 2009) was used in the creation of these

learning designs for our school. Adaptations and modifications are suggested to begin a STEM improvement effort, and testing these learning design cycles in practice has allowed multiple opportunities to learn how to design and implement changes within a school's context. These learning designs have provided necessary hands-on experiences which aided in the overall development of a STEM education roadmap for student learning. To actually increase the number of students entering STEM career fields, specifically USUR students, these ideas are just the beginning of the STEM Education Roadmap for students and teachers.

Chapter 4

STEM ROADMAP for Students and Teachers

Chapter 4 reveals what was learned through the three STEM learning design cycles and their influence on the improvement effort. The learned lessons are summarized as 7 principles and the processes and products that emerged from the learning are shared so that other educators can test and adapt them for use in their schools.

Mapping the Improvement Effort

There are significant numbers of barriers that prevent students, specifically USUR students, from entering STEM career fields of study. When reviewing the STEM research, one realizes that there exists a wide variety of STEM education programs, but little evidence that these programs have helped to solve the STEM problem. Most experts propose a set-solution matrix for every school context. However, these types of solution recommendations have not been effective, as USUR STEM problem persists. The STEM experts have the necessary knowledge; however, their ability to transfer their knowledge to positively impact students within school systems has not occurred. Clyburn (2013) quotes Bryk as saying, “We have lots of good ideas about how things could be better, but often in education we move to immediately implement reform ideas at a very large scale, even when knowledge about how to execute these ideas is lacking” (2013, p. 4).

Dr. Bryk states that there is a difference between practical knowledge and research knowledge. He suggests utilizing Improvement Science methods because they combine the “Knowledge Of” with the “Knowledge How” (Bryk, 2012, CPED Conference) to produce educational outcomes that have the potential to work in practice. Included in this research document are recommendations which could potentially and incrementally change schools if the solution ideas were adapted and implemented according to the needs of local school systems. These methods are not cure-alls, but rather big concepts aimed at reducing barriers that have caused students, specifically USUR students, to not select STEM fields of study. The educational leader’s ability to create change (Knowledge How) while developing a collaborative culture with their teaching staff is essential if change is to occur happen within a school system. It is expected that STEM school improvement teams will modify and adapt the STEM solution ideas to work within the contexts of local school districts. Educational practitioners who understand the system, the community, and the local STEM needs of their students will make the biggest differences in removing barriers for USUR students to enter STEM fields. These professionals have the “Knowledge How” (Bryk, 2012, CPED Conference) which has been a missing component of past STEM reform efforts.

Educational leaders must engage and empower their teaching staff, students, and school community within the overall STEM improvement efforts if improvements are going to be meaningful. This STEM improvement model will explain why and how Improvement Science tools are practical and will help the educational leader design and implement local STEM improvement efforts designed to reduce USUR student barriers. When developing cycles of improvement, the resulting factors of this study utilize the six

elements of a PDSA cycle suggested by Park (2013): (a) Intent Statement; (b) Aim Statement; (c) Audience; (d) Deliverability; (e) Team Lead and Members; and (f) Key Resources and Experts (p. 9-10).

Before describing the “Knowledge How” (Bryk, 2012, CPED Conference) to implement a change initiative, education leaders must also be familiar with research surrounding the use of STEM education programs. Practitioners who have the “Knowledge Of” (Bryk, 2012, CPED Conference) STEM are the leaders who will be able to implement ideas that have the potential to work in practice. Combining the Theory of Profound Knowledge (Langley et al., 2009) with research on USUR students in STEM education has led to the development of the STEM Education Roadmap: Seven Core Principles of Success for educational leaders to utilize within their schools. These seven core principles, if used by educational leaders, have the potential to positively impact all students, specifically USUR students who may then opt to pursue a STEM education.

In preparing for this improvement journey, I contacted Dr. William Kerr, superintendent of Norwin School District and a STEM leader. When asked about how his district attracted followers to help with the development of Norwin’s STEM Innovation Center, he spoke about a comprehensive approach that involved educators, parents, students, and the business community. Kerr states that when planning complex problems, he utilizes three levels of planning: Strategic (big picture), Operational (how to get it done at the school level), and Tactical (individual classroom) approaches.

As an educational leader, I created a STEM Education Roadmap that consists of seven core principles for success with STEM education initiatives. This list is intended

to increase the number of USUR students studying STEM fields of learning. The list reflects my literature review concerning the removal of barriers to STEM education of USUR students and the use of Improvement Science tools. These tools help educational leaders to operationalize their “Knowledge How” (Bryk, 2012, CPED Conference). The seven principles include

STEM Education Roadmap: Seven Core Principles for Success

1. Utilize a Professional Learning Community which allows teachers to understand, recognize, and work to eliminate student barriers toward STEM education.
2. Develop student and teacher understanding about growth mindsets, providing students with the skills to productively persist when faced with challenging tasks.
3. Promote STEM instructional strategies and best practices that will inspire and motivate students through project-based learning, hands-on experiences, and formative assessments.
4. Enhance the quality of teacher-student feedback (formative assessment) to promote student resiliency towards learning.
5. Embrace and utilize instructional strategies that support the 21st century learner across all subject areas. These strategies will enhance students’ innovation, creativity, critical thinking, communication, and teamwork skills.
6. Build local cooperative relationships between education and the business community to connect students with STEM-related experiences in and outside of school.
7. Provide educators with STEM learning opportunities at the school building level, along with education and training opportunities outside of the district to foster a Professional Learning Community.

These Seven Core Principles (Appendix A) are not new ideas, for they focus on elements of other STEM initiatives educational leaders have heard and seen before. To make this list useful for the educational practitioner, a review of potential Improvement

Science tools and strategies is essential, since the seven core principles by themselves cannot promote or monitor a collaborative, complex change process. The reality of leadership in today's schools makes it easy and tempting for a principal to become wrapped up solely in the daily roles and responsibilities of the position. For example, Pennsylvania has implemented a new teacher evaluation system, a new school performance profile, and revised curriculum standards to meet the federal common core standards. The implementation of these mandated initiatives has been time consuming and has demanded much change in educational systems and processes. Implementing these major, mandated changes can easily lead a principal to feeling overwhelmed and there is little time left to pursue other initiatives. Therefore, to successfully implement the Seven Core Principles of Success for increasing STEM education for students who are under served and underrepresented, principals must be systematic and intentional with their problem identification, understanding, and strategic planning for incremental change. Rather than being an extra burden for administrators, the Seven Core Principles of Success are designed to foster step-by-step implementation over time through a sequence of improvement cycles.

That implementation starts with a very important first step of developing mutual understanding of the problem with all who are involved with the plan. In regard to solving the STEM education problem in our district, it was crucial to help all members of the planning team develop a more sophisticated understanding of the barriers that impact underserved and underrepresented students in their pursuit of a STEM career. By understanding the complexity of the barriers, stakeholders also come to understand that eliminating these interrelated barriers will require a multi-faceted and multi-year process.

Additionally, that process must be embedded within the everyday routine of the school if change is to occur, be accepted and supported, and become institutionalized within the school and district.

Before undertaking this kind of collaborative process to understand and describe the problem, it is important for an educational leader to work with his or her planners and call on the expertise of others who may have started a similar journey and may provide greater insight. Under Dr. Kerr's leadership, the Norwin School District applied for a \$2.5 million state grant to bring to life the dream of a Norwin School District STEM Innovation Center for Teaching and Learning. Dr. Kerr noted that in order to attract followers from all sectors of the community to help develop the center, it was necessary for planners to take a comprehensive approach to involve educators, parents, students, and the business community. Kerr further advised leaders who are working to understand and solve complex problems to utilize three levels of planning: strategic (big picture), operational (how to get it done at the school level.), and tactical (individual classroom) approaches to effectively implement change across the curriculum to develop STEM education. Kerr's remarks regarding his district's STEM improvement efforts fully confirm the overall complexity of his STEM improvement effort (Kerr, 2014, personal communication).

Issues of this degree of complexity, and which involve a wide range of stakeholders, are perfectly aligned to the purpose and tools of Improvement Science. Two of those tools, an improvement map and a driver diagram, were used both to frame and advance STEM improvement efforts in my district. What follows is a description of each tool, an

explanation of how it was used, and suggestions for leaders who want to apply these tools to complex problems in their own schools and districts.

STEM Improvement Map

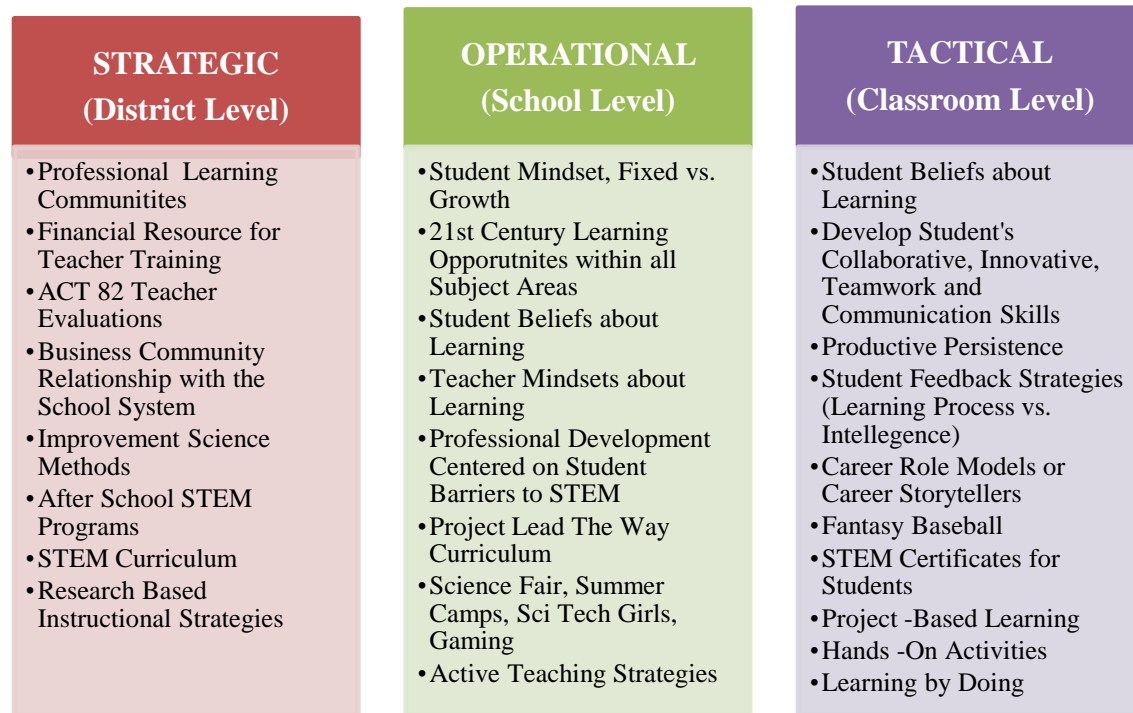
An improvement map is an integral tool of Improvement Science and is especially effective when solving complex problems at the practitioner level. A program improvement map encourages critical thinking about how complex systems operate “in tandem with one another” (Bryk, 2010, p. 15). Practitioners can approach it like a roadmap, serving as “a coordination device for diverse actors. It seeks to keep the improvement priorities of a network and their interconnection in explicit view as participants work on different parts of the problem” (Bryk, 2010, p. 15).

Figure - 4.1 depicts an improvement map created for a school within a public school district. To be useful, an improvement map must involve the entire school district organization and include all levels of operation. The improvement map in Figure 4.1 displays three important levels that describe the problem across the overall district, within the individual school building, and at the classroom level. By describing the particular parts of the problem across all levels, those in charge of planning may begin to understand and recognize how each of the three components functions separately. As such, they can work together to reduce barriers to USUR students intending to study STEM fields. Additionally, the improvement roadmap will help administrators and all who are assisting them at all levels design solutions for the desired outcome of STEM education improvement.

It is important to point out that this STEM improvement map was developed to meet the school district's local needs and was formed following a comprehensive review of STEM literature. The STEM improvement map considers the perspectives of central office administrators, principals, teachers and students. In doing so, the map provides a visual tool that will help all of those involved within the district to coordinate this STEM improvement effort within the district and will attract expert assistants from outside the district to join in the initiative. The improvement map also clearly shows that a person's role and level of responsibility, while unique, will merge with other unique responsibilities in the district and, ultimately will contribute to the district's approach.

Creating and employing a STEM Improvement Map will enable the educational leader to select and see connections between the aim of the improvement efforts and the Seven Core Principles for Success. And, just as importantly, the map will provide principals informed ways to incorporate and prioritize small pieces of the STEM problem into manageable and relevant courses of action with specific action points and solutions.

Figure 4.1 - Program Improvement Map for STEM



As Figure - 4.1 illustrates, STEM education can be examined through three specific viewpoints, that each providing possible solution ideas which reach across the strategic, operational, and classroom levels. A districtwide perspective ensures that improvement maps are powerful tools for highlighting the avenues to communicate the STEM improvement effort across a school system. With the improvement map as a guide, principals and teachers might be encouraged to implement and discuss various STEM interventions or solutions. The improvement map helps illustrate that developing and delivering a STEM curriculum is crucial at the strategic level and will not happen without actions at the school level. For example, the district determination to implement STEM curriculum leads to the school district choosing the materials, such as the curriculum, professional development, and active teaching strategies found in Project

Lead The Way. Just as importantly, an improvement map calls for improvement efforts at the tactical level, such as provision of career role models and career storytellers, hands-on activities, and problem-based learning.

Any improvement map, to be effective throughout the improvement effort, must be revisited and specifically discussed. Since each solution idea or action point is clearly inter-connected across each of the three levels of planning, a change at one level will cause both a change and a need in the other two. Keeping up with this inter-related process requires the leader constantly to monitor and assess the improvement map, with adjustments as necessary, so that it continues to depict the present status of the system and to determine its needs in the future. Because the central office administrators, building principals, and classroom teachers work together and are guided by this Improvement Science tool, their STEM knowledge will increase and their ability to create and pursue innovative solutions will expand. As knowledge is acquired, additional solution ideas will be discovered thus furthering and refining a district's multi-stepped and multi-year STEM education efforts.

STEM Driver Diagram

To further enhance the work of the STEM improvement map, an educational leader can employ a second important Improvement Science tool: a driver diagram. The STEM driver diagram fosters the collaborative understanding of a problem so that all who are involved in developing the programs might focus their thinking around possible

solutions. With regard to STEM education, leaders can utilize a driver diagram to create a STEM dialogue specific to their own school and school district's STEM needs.

STEM issues of this complexity need tools to further frame and advance improvement efforts within respective school districts and the driver diagram is such a tool. A simple driver diagram has three components: aim or outcome, primary drivers, and secondary drivers. Illustrating specific change ideas through a driver diagram helps the educational practitioner collect and communicate related ideas in one specific location. This collaborative practice allows ideas to be easily seen by the district's STEM stakeholders. As the local STEM knowledge increases, the educational leader can work with the developers to adapt the driver diagram solution ideas as needed to ensure that the district STEM solution ideas result in the desired change.

When building the district's STEM driver diagram, it will be necessary to adapt the improvement language to ensure all program planners can focus solely on STEM improvement ideas. Replacing technical driver diagram language with more recognizable synonyms like STEM Goal, Primary STEM Cause(s) and STEM Solution(s) ideas allow all planners to enter into collaborative and intentional inquiry and learning.

The following simple driver diagram illustrates how to use the tool to create a common vision among who are involved in building the program. This STEM change idea was developed to meet the school district's local needs and was formed following a comprehensive review of STEM literature. Guided by the STEM improvement map, the diagram makes connections between the improvement efforts of the Seven Core

Principles of Success and provides a visual that will foster collective dialog around STEM solution interventions directly aimed at specific STEM causes.

Figure 4.2 - Driver Diagram for STEM

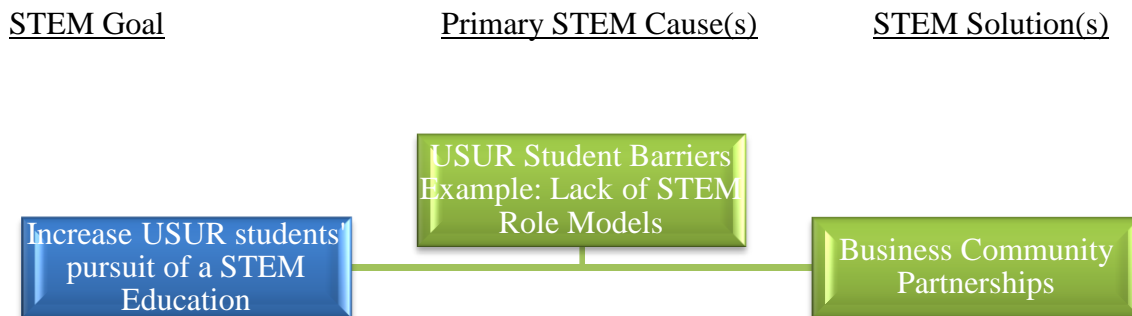
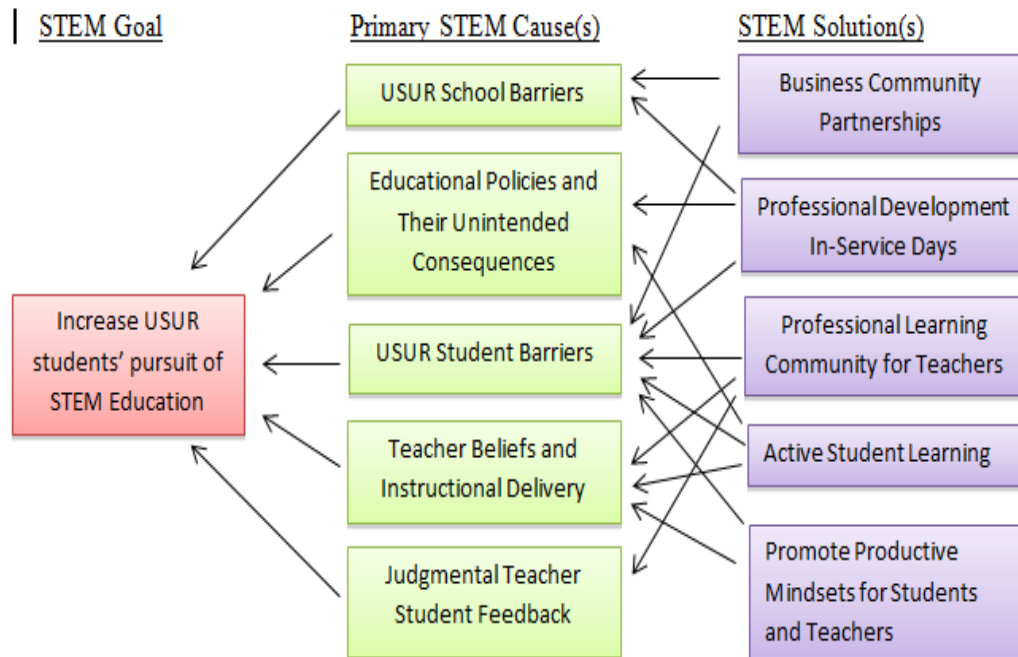


Figure - 4.2 illustrates a particular STEM cause and a STEM solution. To be effective, the driver diagram should help each district practitioner understand the problem at the strategic, operational, and tactical levels. In this illustration, the outcome or STEM Goal of this STEM driver diagram is to increase USUR student pursuit of a STEM education. The identified causes of the barriers to USUR students pursuing STEM education is the lack of role models. The idea is to create local business community partnerships that will encourage STEM career role models to collaborate with the school district. This driver diagram allows specific parts of the problem to be seen, so that, along with specifically designed solutions ideas, individual components of the problem might be addressed. Educational leaders are thus able to connect multi-layered, multi-dimensional problems that now are visually interconnected through the illustration.

Increasing USUR student pursuit of a STEM education is a complex problem and educational leaders must create solution ideas that reach across the strategic, operational, and classroom levels. A driver diagram will allow the educational leader and the district

team to focus on the causes and solution ideas around STEM improvement. In the illustration below, a more complex driver diagram, five interrelated causes are displayed along with five possible interrelated solution ideas.

Figure 4.3 - STEM Driver Diagram Illustrating Five Interrelated Causes and Five Interrelated Solutions



The STEM driver diagram illustrated in Figure - 4.3 displays five examples of barriers that prevent students from pursuing STEM education along, with five examples of potential STEM solutions. Due to the complexity of the problem, the illustration highlights multiple solution ideas which are associated with multiple causes. This illustration allows all who are involved in removing the barriers to see how each solution idea is tied to other barriers and how all solutions and causes are tied to the overall STEM goal. To solve the teacher beliefs and instructional delivery component of the STEM diagram for example, an educational leader may lead a professional learning community

which focuses on the integration of 21st century skills within all subject areas and across the curriculum.

The 4.3 driver diagram serves as an organic collection of district ideas around the STEM improvement effort. This changes as the district moves forward, one step at a time, toward the overarching STEM goal. The solution ideas span the strategic, operational, and tactical levels and, in doing so, further strengthen the collaborative nature of both Improvement Science tools, the improvement map and the driver diagram. Driver diagrams help all district practitioners play strategic and specific roles that enable each practitioner to join in the school district's overall STEM initiative. These two tools are powerful change agents and can help all improvement members to develop new STEM knowledge to leverage change and further propel the district towards the desired outcome.

Leading this complex improvement cycle process requires that educational leaders know how to effectively and strategically select when and how to begin, to reassess professional STEM knowledge, and when to modify the improvement map or driver diagrams. Developing a teaching staff's collective capacity within a system, and working towards a common STEM goal will build the understanding of each educational practitioner. As a result, each person within the professional community will learn together. Just as the Seven Core Principles for Success are designed to be implemented incrementally, the driver diagrams and their solutions ideas are meant to be sequenced through improvement cycles which are multi-stepped and multi-dimensional.

An Improvement Tool for Change: PDSA Cycle

Improvement maps and driver diagrams are two powerful, strategic, (school district level) and operational, (school level) planning tools which can help a school district and a school building foster collaboration among administrators and teachers when working towards a STEM improvement goal. To complete the planning effort at the tactical, classroom level, there is a third Improvement Science tool educational leaders can use: a plan-do-study-act (PDSA) cycle. Using a PDSA cycle creates learning opportunities for school district practitioners to investigate, learn, and develop effective STEM solution ideas through individual and collective practice for implementation. A PDSA cycle serves as a learning process for a school system that encourages each educator to advance their professional knowledge. A PDSA cycles focused on the local STEM needs of their students allows the district to create an avenue for teacher learning. New learning opportunities and processes about STEM education develop the critical thinking skills necessary for STEM solution ideas within a STEM driver diagram.

PDSA cycles are short improvement cycles that last 90 days. According to Bryk (2010), the goal of PDSA cycles is to “test fast, fail fast” (p. 28). Through each implemented PDSA cycle, every teacher functions as an active learner gathering specific student information related to STEM solution ideas presented within the STEM driver diagram. A PDSA cycle empowers individuals to work collaboratively with their colleagues to discuss locally designed improvement methods. The responsibility of the educational leader is to highlight each teacher’s learning and to communicate the information throughout the school building and across the school system.

The aim of each PDSA cycle is to provide teams with learning opportunities for both students and teachers as they relate to the STEM solution ideas within their driver diagram. As a group, teachers can precisely pinpoint local STEM knowledge within a specific school system and collaboratively connect the learning from each interconnected STEM solution idea to advance the district's STEM goal. Through each cycle of improvement, the district's STEM knowledge increases, along with the STEM solution ideas initiated through a multi-step process that furthers the district's STEM efforts. It is critical that with each new idea, the improvement team documents the learning that occurred through each revision of a PDSA cycle. As local-level learning occurs, the educational leader must be systematic and intentional in providing collaborative opportunities for the classroom practitioners to learn from the outcome of each PDSA cycle. Using the evidence from each cycle of improvement, the staff becomes a dynamic force that is actively learning and developing valuable STEM interventions at the local level.

Leadership: When and How to Begin an Improvement Effort

While STEM improvement maps, STEM driver diagrams, and STEM PDSA cycles are promising Improvement Science tools, these tools alone will not cause change within a school. All too often in the world of education, the word “change” is seen as a method to correct problems. Just like principals, teachers can become occupied in their daily roles and responsibilities and feel that there is little time left to pursue change ideas or initiatives. The method a leader selects to deliver an improvement message to a

faculty and staff cannot simply be a good sales pitch asking teachers to change their current practices. Indeed, if the improvement effort is perceived as another add-on, it will gather little traction and result in failure. Similarly, effective implementation of an improvement effort does not start with the educational leader telling the teachers what is wrong with their instructional practices. Rather, effective implementation begins with the pursuit of mutual understanding of the problem by all who are involved.

The STEM Education Roadmap: Seven Core Principles of Success was designed for the educational leader who has an interest in addressing a school district's STEM needs through a purposeful, multi-layered, and multi-stepped Improvement Science process. Educational leaders who plan to utilize Improvement Science techniques must begin their STEM improvement efforts long before creating a STEM roadmap for their district. Using Langley's et al. theory of Profound Knowledge (2009, p. 76), a leader must develop an appreciation for a system which he defines as "an interdependent group of items, people, or process working together" (p.77). Building the leader's current STEM knowledge enables the leader to develop theories and ideas specific to the school district's STEM needs. Once a leader develops a deep understanding of the people and process within a specific school district, the leader will be able to benefit from and effectively use the Improvement Science tools that will engage and empower a professional teaching staff.

Increasing USUR students' pursuits of a STEM education is an intricate problem, and these powerful Improvement Science tools help educational leaders make district improvement efforts that are accessible to all and that keep the process systematic, intentional, and manageable.

Improvement maps, driver diagrams and PDSA cycles are essential elements Improvement Science tools that allow for educational leaders to do the behind-the-scenes work that is necessary to solve complex problems, with getting classroom teachers involved with STEM solution ideas being the goal. The greatest change for increasing USUR students interested in pursuing STEM education rests at the classroom, tactical level. Building a collaborative STEM improvement plan takes an entire team working through solution ideas. Thus, teachers and leaders need to work together in practice so that they might share their approaches in advancing toward the goal of increasing USUR students in STEM education.

What is Fantasy Baseball?

A Fantasy Baseball math program is a hands-on, integrated math program that teaches students math through baseball statistics and simulated game play. The program is designed to create student interest and excitement around a mathematical game for those students who have typically struggled with mathematical concepts. While playing the game, students develop the following math skills: proportion, ratios, algebraic thinking, geometry (real world math problems), statistics, and probability while being actively engaged in the game. Besides developing math skills, students have hands-on experiences with learning and expanding their 21st century skills, innovation creativity, critical thinking, communication, and teamwork skills.

Why Fantasy Baseball as a STEM Solution Idea?

The Fantasy Baseball math program was selected as a solution idea because the program has the potential to positively impact both students as well as the classroom teacher. The first aim was to combat the barriers underserved and underrepresented students face when pursuing a STEM education. Fantasy Baseball has the potential to combat the following three student barriers: First, by playing the game, the stereotype that girls are not good at math will be challenged. Second, the disidentification that occurs when students underperform in math and start to devalue the subject will be reduced. Third, students will begin to believe that they can successfully learn math and their sense of self-efficacy will grow.

The Fantasy Baseball math program utilizes many active learning strategies. According to the *Engaged to Excel* report (2012, p. 17) active learning strategies increase students' retention of information, enhances students' academic performances, and induces more positive attitudes toward STEM disciplines.

The second aim of Fantasy Baseball was to impact teachers' internal biases towards USUR students through the use of active learning strategies with students who are in their classrooms. Due to the number of state tested mathematical concepts, a majority of teachers believe they must cover as many concepts as possible within their instructional day. As a result, they utilize "drill and kill" instructional methods within their classrooms. These methods often reinforce teachers' internal biases about the abilities of USUR students learning math. However, through the use of active learning strategies, such as Fantasy Baseball, teachers' personal beliefs and low expectations for

the USUR student to learn math are mitigated because of the success students experience while playing the game.

Fantasy Baseball Improvement Cycle

Plan: Reduce “drill and kill” math process problems, actively engage students in math while increasing student self-efficacy.

Do: Utilize instructional strategies, such as gaming, to entice and motivate students to learning ratios and proportion problems.

Study: Determine if USUR math students engaged and motivated to learn mathematical concepts and if students’ math self-efficacy increased?

Act: Determine if teachers used active teaching strategies and transferable teacher knowledge in practice.

Fantasy Baseball Projected Outcome

The fantasy baseball deliverable aim is to develop USUR students’ sense of confidence and competence in math while reducing student barriers. Through this deliverable, the goal was to make math fun while positively impacting students’ mindsets about math and expanding teachers’ instructional practices. The Fantasy Baseball math program is a hands-on, integrated math program that teaches students through baseball statistics and simulated game play. Participating teachers were required to attend professional development activities that focused on active and effective teaching and learning strategies.

Is Fantasy Baseball a Must STEM-Solution Idea?

While Fantasy Baseball can be a very effective learning tool, it is not a “must” STEM-solution idea. This solution idea was developed as a result of individual system needs of a school building and the professional staff within. The educational leader believed that the fantasy baseball program had the potential to impact two of the STEM causes, Student Barriers and Teacher Beliefs/Instructional Delivery, within the STEM driver diagram by offering professional training to teachers and by utilizing active student learning strategies. Any program or idea that reduces USUR student barriers while encouraging educational practitioners to utilize active teaching will increase USUR student pursuit of a STEM education. For a driver diagram of the Fantasy Baseball program, see Appendix B.

A Career Role Model or Career Storyteller as a STEM-Solution Idea

A STEM career storyteller program provides STEM professionals with the opportunity to present STEM career information to students within their local school. STEM professionals are invited to provide students with dynamic work stories or through interesting presentations and/or demonstrations. The power of the career role model or storyteller program is created through student relationships that develop with STEM professionals from their community.

Why Career Role Models as a STEM-Solution idea?

The STEM career storyteller and the career role model program were developed as a result of an extensive review of the barriers that significantly impacted USUR students and their pursuit of a STEM education. One specific barrier seemed to span all areas of the literature: lack of role models. Not having a person whose behavior, example, or success is emulated by others, especially by younger people, is a significant obstacle that both limits and shapes student identities and career choices. The National Academies of Science (2011) quotes Hill, Oettrus & Hedin (1990), lack of knowledge and familiarity on the part of UR (underrepresented) minorities in terms of what constitute as a career in STEM may contribute to their limited presence in these fields” (p.99). In a survey of over 1,000 scientists and engineers, Cummins (2004) learned that just over half (52%) had been influenced in their choices of careers by a visit to a scientist’s or engineer’s place of work, and nearly a quarter (23%) had been influenced by a scientist or engineer visiting their school (p. 14). Clearly, students and teachers benefit from having direct access to scientists and engineers on a regular basis in the classroom. Bayer Fact Surveys from 1995-2011 reports, 2012,

A STEM role model program has the potential to combat the following USUR barriers to STEM:

- Role models can reduce negative stereotypes when students are able to see people like themselves within the career.
- Role models can help students see their struggles as a normal part of the learning process—growth mindset. (p.19)

Career Role Model or Storyteller Outcome

The aim of the role model deliverable is to provide USUR students the opportunities and supports necessary to develop their general understanding of what STEM careers are, while increasing their confidence by reducing the barriers that prevent them from pursuing a STEM education. For example, the program would provide explanations and illustrations of what engineers actually do. This is important because in many circumstances, students believe that engineers work on inert math problems all day as isolated individuals. What role models help students discover is that effective engineers work on real-life problems as members of a team. That discovery helps USUR students recognize the value of their teamwork and communication skills as being strengths for a potential STEM career. This recognition might help them alter their perspectives of engineering positions and encourage them to pursue a STEM career.

How to Attain Career Role Models for Your School

Depending upon the local school district community, there are multiple avenues to engage STEM professional as role models. One suggestion involves reaching out to business clubs, such as the local Rotary Club. A second suggestion is to mount a business community letter/email campaign asking for STEM career role models or storytellers. The simplest way to find STEM role models is to ask parents of children enrolled at the school. The educational leader who knows their community should know which resources to tap. For example, in my own practice, I had a unique opportunity to talk with a group of STEM professionals. During a short conversation, I described my

personal narrative of growing up not knowing much about STEM professionals, since the majority of my family and friends worked in service or manual labor positions. I then expressed the need for our students to have positive role models who were not athletes and celebrities. This short “elevator speech” enabled our school to kick off a Career Role Model Program.

Is a Career Role Model or Career Storyteller a Must STEM Solution Idea?

A career role model or a career storyteller---at least some form of “must” STEM solution idea. This solution idea has no negative aspects, since the students, school, and teachers benefit from this type of program. What is more, the program is cost free and offers the potential to create collaborative partnerships among a school district, the business community, and with STEM professionals. In addition, increasing USUR student knowledge of STEM professional careers has the potential to impact two STEM causes (USUR School and Student Barriers) by creating business community partnerships and by promoting productive mindsets. While a career role model program is effective, a productive business community partnership may also lead to more advanced opportunities for USUR students, and for all students. Such opportunities might include job shadowing, mentorships, internships, and employment. Any business community partnership which reduces school and student barriers to STEM will increase USUR student pursuit of a STEM education. For a driver diagram of the career role model or career storyteller program, see Appendix C.

Why Professional Learning Communities as a STEM Solution Idea?

When considering solution methods for complex problems, like increasing USUR student pursuit of a STEM education, it is important for educational leaders to select specific strategies that promote professional learning opportunities for teachers and other members of the school staff. After selecting Improvement Science as a method for educational leaders, it was necessary to select a training approach that would create collaborative learning opportunity for teachers.

Establishing a Professional Learning Community (PLC) is essential to any school improvement effort, and it quickly emerged as a valuable tool for our district and teachers. A PLC can be the “most powerful strategy for having a positive impact on learning [how to] facilitate the learning of the educators, who were the students through the PLC process” (Dufour and Marzano, 2011, p.63). According to Honey (2014), a professional learning community can help teachers identify and pursue ongoing learning and professional growth. Both of these processes are strongly related to teacher self-efficacy and instructional effectiveness (p.126). Dufour and Marzano (2004), characterized PLCs as “a systematic process in which teachers work together to analyze and improve their classroom practices. Teachers work in teams, engaging in an ongoing cycle of questions that promote deep team learning. This process, in turn, leads to higher levels of student achievement” (p. 9).

How to Select or Begin Your STEM PLC?

The STEM improvement goals within the STEM Education Roadmap and driver diagram will help an educational leader establish the learning goals of his or her locally

designed STEM PLC. To begin the PLC STEM effort in my school, a portion of the teaching staff was asked to read the book, *Teaching Minds: How Cognitive Science Can Save Our Schools*, by Roger Shank (2011). This book was selected because it challenges many status-quo educational practices about teaching and learning and provides specific insights into the many interconnected and institutionalized STEM barriers, such as educational policies and their unintended consequences, teacher beliefs and instructional delivery and unique USUR student barriers.

Is Selecting “Teaching Minds” for Book Study a Necessary Solution Idea?

While the book, “Teaching Minds” was specifically selected as a book study to address the professional needs within our building, it is not a “must” solution idea. Each educational leader should begin by analyzing USUR students’ STEM needs within the district in combination with the needs of the teachers within the district with regard to STEM issues, as well. That information can then be used to select a book to set a foundation for a district’s STEM PLC improvement effort. For a driver diagram of a Professional Learning Community, see Appendix D.

STEM Professional Learning Community STEM Outcome

The aim for creating a STEM PLC process was to provide focused discussion and learning opportunities for teachers supported by a safe environment. Professionals could critically examine their own practices while learning from other professionals. The goal was to influence, support, and inspire educators to reflect on their instructional methods,

learn from that reflection, and put their learning to work through thoughtfully designed classroom activities where students could learn in a hands-on setting.

Are PLCs a Must STEM-Solution Idea?

Yes, PLCs are a “must” solution idea. Through our PLC effort, teachers were engaged in spirited bi-weekly discussions about their classroom instructional practices. The discussions led all teachers to share instructional materials, and several teachers invited their colleagues to visit their classrooms to observe how they were implementing some of the instructional ideas discussed during the PLC meetings. “The most powerful strategy for having a positive impact on learning is to facilitate the learning of the educators, who were the students through the PLC process (Dufour & Marzano, 2011, p.63).

PLCs are not only an effective educational strategy, but they are also a cost-effective practice which all school districts can afford to implement since there are no costs associated with good professional dialogue. This STEM PLC design was developed as a result of teachers’ needs within a specific school building. The educational leader believed STEM PLC had the potential to impact three of the STEM barriers that were embedded in the school culture (educational policies and their unintended consequences, teacher beliefs and instructional delivery, and USUR student barriers) within the STEM driver diagram. If interested in viewing the STEM PLC driver diagram please refer to the Appendix D. Any PLC that reduces student barriers to STEM while increasing teacher knowledge will increase USUR students’ pursuit of a STEM education.

Fantasy Baseball, Career Role Models, and STEM PLC designs are three actual improvement efforts that were applied in practice with students and teachers. Through each experience, significant learning has occurred and impacted future school-based action related to the overall improvement effort of increasing USUR student pursuit of a STEM education. The three efforts addressed a common STEM issue: Student Barriers.

Why are USUR Student STEM Barriers so Important?

The literature review previously discussed is designed to provide the educational leader with an understanding of the types of barriers that prohibit USUR students from pursuing a STEM education. But the power of this improvement model does not hinge on the understanding of the educational leader. The power of the model is realized by developing the collective capacity of the educational professionals within a specific school and or school system.

Once the educational professionals within a school system have a firm understanding of the barriers that prohibit students from pursuing a STEM education, they then can be active collaborators within a STEM improvement effort. The overall complexity of this STEM improvement effort, combined with the number of moving parts within a school system, present an issue that cannot be addressed by an educational leader who is working in isolation. And even though it helps for the educational leader to create a STEM vision and a conceptual design, it is through effective communication of that vision and working with teachers that the original vision becomes reality.

To this end, the STEM Education Roadmap: Seven Core Principles for Success can serve as an effective model when one is developing a school's specific STEM plan.

Once all parties within a school system understand student barriers, they will more easily be able to discuss and create improvement efforts that are specific to their school system. Many STEM improvement efforts have not proven to be effective because the strategies they employed were not generated for a specific community and school system and were not part of a shared vision for improvement.

What are USUR Student Barriers to STEM?

The number of barriers USUR students face when pursuing a STEM education is significant. Student self-inflicted barriers, along with traditional STEM barriers which are developed as a response to interactions and feedback from adults and educators, have a limiting effect on the careers students pursue. These barriers include stereotypes, disidentification, negative perceptions of self-efficacy, deficit perceptions, implicit bias, and drill and kill instructional methods, lack of 21st century skills, mindsets, and negative feedback. The list below provides an illustration of each:

- Stereotype threat: Girls are not good at math.
- Disidentification: This occurs when students underperform in math and start to devalue the subject as a result.
- Negative Self-efficacy: Some learners have a preconceived belief about his or her inability to succeed in specific areas of math.
- Deficit perspective: Some educators are inclined to define students by their weakness rather than their strengths (i.e., John is not a good technical writer).

- Implicit bias: Stereotypes or attitudes can affect educators' understanding, actions, and decisions unconsciously (i.e., urban students are not interested in science or math).
- Drill and Kill instructional methods: Students are asked to complete low-level computation and are never exposed to using critical thinking to solve real-world problems in math and science.
- Lack of 21st century skills: Classrooms do not promote teamwork, problem-solving, critical thinking, or a global perspective.
- Mindsets (Fixed vs. Growth): Teachers and schools spend their time documenting intelligence or talent instead of developing it.
- Student feedback that does not build resiliency towards learning: Feedback is evaluative, summative, and general, not helping the students to see their way forward.

How to Structure Efficient and Effective Professional Development

Before focusing on the student barriers to STEM, school leaders should have a firm understanding of the district's professional development model. A professional development model has the power to propel a STEM improvement effort. Through my 14 years of experience as a principal, I have admittedly, led both effective and ineffective professional development days. Creating differentiated models of professional learning has proven to be the most effective approach, since not only are teachers more engaged, but educational leaders are also better able to offer specific ideas, supports, and resources for professional growth.

The Norwin School District serves as an excellent example of a differentiated professional development plan regarding STEM improvement efforts. Through strategic district planning, Dr. William H. Kerr, Superintendent of Schools, has implemented a Norwin School District STEM professional development plan (2013):

Our professional employees are required to complete 14 hours of research and development each school year. Beginning in the 2013-2014 school year, we will encourage teachers to use their hours to investigate and develop STEM initiatives in the District, their school, and classrooms. As part of our District's professional development initiatives, we encourage administrators and teachers to engage in book studies in the areas of STEM Education, Innovation, and 21st Century Learning. One such example of a book study that occurred this school year was our administrative group who read and discussed *Creating Innovators* by Tony Wagner. Finally, as part of our three-year teacher induction that all newly hired teachers must attend, we provide an entire training session in year two on STEM topics and the integration of STEM across the curriculum. (STEM in the Norwin School District, 2013, p. 2)

Professional Development Planning Tool for Educational Leaders

As a STEM solution idea, a professional development planning tool will allow educational leaders to design STEM professional development activities centered on the specific needs of the educators within their school building or district. For example, if the entire staff exhibits through their discussion and practice that they share or contribute to a specific student barrier (ex. stereotype threat), then it would be appropriate for a

large group to take part in professional development that focuses on eliminating this source of bias. On the other hand, educational leaders can identify teacher leaders with specific expertise or knowledge to lead a differentiated professional development model. Each teacher would only be required to participate in sessions for which they had an identified need or that would present them with an opportunity for growth.

Ultimately, the goal of professional development is to enable an entire staff to quickly acquire the understanding and skills they need to address and to remove student barriers to STEM. Once teachers have a shared understanding of the barriers and what they can do to eliminate them, they will be better equipped to actively participate in providing valuable feedback and knowledge which will help the district to design their local STEM professional development and improvement plan.

Figure 4.4 – Professional Development: STEM Barrier Planning Tool

Rate your knowledge of each concept on the following chart.

Student Barriers	Never Heard of it	Minimal Knowledge	Basic/General Understanding	Solid Understanding	Mastery
Stereotype threat					
Self-efficacy					
Disidentification					
Deficit Perspective					
Implicit Bias					

Figure – 4.4 illustrates how to gather information about teacher understanding of specific STEM barriers experienced by USUR students. Using the results of the survey, educational leaders can quickly identify shared areas of need and likely teacher leaders, as well as, establish effective and differentiated professional learning opportunities.

Is Understanding USUR Student Barriers A Must?

Understanding teachers' knowledge of USUR student barriers to STEM is the core component of this STEM improvement effort, as it spans each STEM solution idea within the driver diagram. If interested in a STEM driver diagram that showcases the importance of student barriers, please refer to the Appendix E.

What other Solution Ideas Could Educational Leaders Choose?

Educational leaders have many important choices to make about how best to develop and implement STEM solution ideas, as these choices will have a direct impact on the overall improvement effort. Each educational leader must use local knowledge of his or her school and staff to determine how a multi-layered and multi-year improvement process should be implemented. There are many important decisions to make: How and when to begin? What type of professional development opportunities will best serve teacher needs? What time frame will produce meaningful results?

Additional STEM-Solution Ideas to Consider

To assist the educational leaders who are committed to increasing the number of USUR students pursuing a STEM education, this section offers additional ideas supported by the STEM literature. These strategies center on the barriers USUR STEM students face. Additionally, the suggested strategies shared were designed specifically for my district and are connected directly to the STEM Roadmap: Seven Core Principles of Success, STEM Improvement Map, and the STEM Driver Diagram.

The depth and the projected timeframe of any improvement effort will determine which of the solution ideas one may want to consider. Once you have utilized the professional development planning tool to assess a staff's USUR student STEM barrier knowledge, improvement planning may begin. Educational leaders are reminded to embed these solution ideas as shared and expected practices for all students, and not as solution add-ons.

For example, one way to embed a particular strategy might be for Pennsylvania educational leaders to utilize Pennsylvania's Act 82 Teacher Evaluation Plan (PDE, 2012). As outlined in this plan, teachers must identify specific professional learning goals. Educational leaders can present a strategy that will help teachers identify goals that will improve their everyday teaching and learning practices. Professional goals targeted to teacher specific needs allow the administrator to determine which topics should be covered within a large-group during in-service day trainings or through a small-group Professional Learning Community.

By closely reviewing the STEM driver diagram, the educational leader better determine if a district should select multiple solution ideas or if it would better to begin with a single-solution idea. Selecting one solution idea at a time is an excellent way to begin and would not overwhelm a district's STEM stakeholders, especially in cases where problems are multifaceted and deeply rooted. A comfortable, collaborative process and a safe and nurturing culture will invite more teachers to utilize their local STEM knowledge to partner with each other and the educational leader to adapt, refine, or tailor each of these STEM solution ideas.

What follows is a description and explanation of these smaller solutions. Each segment presents the specific STEM solution targets, along with potential learning outcomes for teachers and other staff members. Each solution idea is aimed directly at reducing USUR student barriers and is supported with a short summary of supportive literature. This executive summary of the literature is meant to provide the educational leader with specific supports for the choice of a STEM solution idea.

Productive Student Mindsets: STEM-Solution Idea

Student mindsets are important individual characteristics that help to shape how students respond to challenging educational tasks. The educational leader should ensure that everyone, especially the teacher and the educational leader involved in the STEM effort is aware of the power of mindsets. Helping teachers develop clear understandings of formative assessments and the impact that effective teacher feedback can have on how students respond to challenging tasks is critical. In addition, teachers must know how to develop mindsets through intentional interventions. Mindset development and formative assessment techniques are two tactical strategies that are under the direct control of the classroom teacher used positively, these two factors are known to reduce USUR student barriers to STEM. According to Yeager and Walton (2011),

Sometimes the forces in a system are adequate to support learning but students have mindsets that prevent them from fully taking advantages of those forces. As a result, a well-timed and psychologically precise intervention to address those mindsets can unlock the latent effectiveness of educational environments and lead to long-term effects on students' achievement. (p. 310)

A student's mindset is directly impacted by feedback from parents and teachers. Such reinforcement or criticism that students experience can promote either a growth or fixed mindset and is a significant contributor to how students respond when they are faced with challenges.

According to Dweck (2006):

Praising children's intelligence harms their motivation and it harms their performance... Yes children love praise. And they especially love to be praised for their intelligence and talent. It really does give them a boost, a special glow – but only for the moment. The minute they hit a snag, their confidence goes out the window and their motivation hits rock bottom. If success means they're smart, then failure means they are dumb. That's the fixed mindset. (p. 176)

According to Brookhart (2008):

Formative assessment practices can lead significantly to a student's mindset development. "Students are more willing to expend effort in getting and dealing with feedback if they have confidence in themselves as learners, called self-efficacy, Feedback about process shows students the connections between what they did and the results they got. (p. 21)

Developing students' self-efficacy about their intelligence is tied to the type of feedback teachers and parents give to their children. It is critical, then, for all concerned to understand the impact of the response they provide to students is critical. According to Moss & Brookhart (2009) feedback can help students' better cope with setbacks and become more resilient. They see raising student resilience as being a critical way to

increase student motivation to learn and to try challenging things. “Raising student resilience can derail a dangerous cycle for many students who attribute their failure to perform well on classroom tasks to a lack of academic ability. Judging themselves to be incapable of achieving and powerless to change things, they become discouraged and quit trying (Ames, 1992; Boston, 2002; Vispoel & Austine, 1995). Resilient learners, on the other hand, bounce back from poor performances and adversities. They attribute their failures and their success on learning tasks to factor *within* their control. They rebound rather than give up in the face of a challenge. Resilient students believe in their capacity to adapt what they are doing and how they are doing it in order to succeed. (p. 12)

In 2012, Dr. Yeager and his team conducted a study with college students. They asked the students to read an article about how the adult brain remains malleable. Silva’s (2013) article explained that scientists had discovered that brains—even those of adults—grow whenever a person learned something new and challenging. The Yeager team reported that the resilience of the college students who took part in the study increased because they began to perceive challenges as brain builders. Instead of viewing a difficult task as something that might indicate that they were not smart enough to meet the challenge, they now viewed an intellectual challenge as something that made them smarter.

Intrigued by the powerful impacts that mindsets and formative assessment practices can have on learning and achievement, the Carnegie Foundation for the Advancement of Teaching conducted research into the ways that these factors helped students succeed during a community college developmental math course. Through the study, Carnegie established two institutions, Statway and Quantway. Silva (2013) states

that “decades of experience and research on student disengagement and failure suggested that structural changes alone would not be enough to help many students (p. 7). Silva (2013) goes on to link the Carnegie student to the findings from another study conducted by Carol Dweck who, with her colleagues, found that an eight-session course in study skills had little impact on students’ performance. But, when the courses added lessons that address specific psychological factors of learning – i.e., descriptions of the impacts of students’ mindsets about whether their own intelligence was innate or developed through effort – the results were markedly different. Just weeks after the students read the “Growing Your Brain” article, they reported increased enthusiasm and greater confidence in their ability to persevere through the course. These additional lessons not only changed the way students understood intelligence and its relationship to effort, but it also increased student motivation, participation, and academic performance (p. 8).

As a result of their study, the Carnegie Foundation coined the phrase “Productive Persistence”. “Productive persistence is the package of skills and tenacity that students need to succeed in an academic setting” (Silva, 2013, p. 5). Dweck (2006) concluded then that mindset can change students’ beliefs about themselves. The Carnegie Foundation Statway Study (2012) reported that the psychological strategies utilized through “productive persistence” were a key component of students’ success. The percentage of their students who earned math college credit increased from 15% student completion rates to 51% (Silva, 2013, p.5). Developing “productive persistence” and growth mindsets were STEM solution ideas designed specifically for our district’s student and professional needs and are part of the Seven Core Principles for Success.

Is Developing Productive Mindsets a Must Solution Idea for a School District?

Developing productive mindsets is not a “must” solution idea. Selecting to pursue this idea, however, will depend upon a staff’s use of instructional practices. For our district, this STEM solution idea presented the following significant outcomes:

- Enabled teachers to utilize formative assessment techniques within the classrooms
- Increased teachers’ knowledge of growth and fixed mindsets
- Strengthened teachers’ ability to develop students who have a growth mindset
- Enhanced teachers’ ability to develop students who persist when they face challenging tasks (Productive Persistence)
- Empowered teachers to utilize student praise which focuses on learning products and learning processes

Our school believed the Productive Mindset solution idea had the potential to impact three of the STEM causes, USUR Student Barriers, Judgmental Teacher Student Feedback and Teacher Beliefs and Instructional Delivery, within the STEM driver diagram by offering differentiated professional development or PLC plan to the teaching staff. If a district’s STEM needs do not match the productive mindset solution, another STEM solution idea may provide a better fit. If interested in a STEM driver diagram for Productive Mindsets, please refer to the Appendix F.

Integrated STEM and Active Learning Strategies as Multi-Layered

STEM Solution Idea

The integration of STEM 21st century competencies across all subjects will increase student persistence, as STEM course interest, along with increasing students' abilities to transfer STEM knowledge helps students in every area of life.

According to Honey (2014),

Twenty-first century competencies are a blend of cognitive, interpersonal, and intrapersonal characteristics that support a deeper learning of knowledge and transfer. Cognitive competences include critical thinking, innovation; interpersonal attributes communication, collaboration and responsibility; and interpersonal traits include flexibility, initiative, and metacognition. (p. 35)

Integrating STEM with 21st century skill has been attributed to decreasing USUR student barriers. Interest is another factor that can influence learning and an individual's self-efficacy and sense that he or she can be successful in a certain subject.

Honey (2014) states,

With more developed interest, the learner often has strong feelings of self-efficacy and can better self-regulate behaviors to persevere on challenging tasks.

Once an interest begins to develop, it can be sustained through instruction and/or out-of-school experiences, during which the learner often comes to identify with those who represent and pursue the interest professionally (p. 64).

In a case study involving integrated STEM, Honey (2014) reported that project-based teaching increased teachers' self-efficacy and led to greater student participation, and therefore, increased student learning. Project-Based learning "fosters interactions between students and requires communication and collaboration, it can leverage the social aspects of learning in ways that traditional approaches to instruction often do not" (p. 88).

As an example of Project-Based Learning, our middle school elected to implement an integrated STEM program titled Project-Lead-the-Way (PLTW). This project included a course entitled "Automation and Robotics," a course in which our students worked collaboratively with their peers while building and programming simple robots. Students were required to work in groups by using 21st century skills to complete their assignments. PLTW utilized multiple active learning strategies. According to the Engage to Excel National Report (2012), active learning strategies enhance students' STEM learning. They include but are not limited to active experiences that provide feedback such as small group discussion and peer instruction, one-minute papers, clickers and other response systems, problem-based learning, case studies, analytical challenges before a lecture, problem sets in groups, concept mapping, writing with peer review, computer simulations and game and other active learning methods (p.17).

Active learning strategies can be powerful if teachers understand how to apply the strategies with fidelity. If teachers do not have the skill or the knowledge to employ these strategies, they should begin slowly and engage in professional development to upgrade their understanding and skill.

Active Learning Strategies Professional Development Planning

Tool for Educational Leaders

The active learning professional development analysis and tool can be used to provide the educational leader with staff-specific information relative to their understanding of specific active learning strategies. The strategies included in the example below are related to those described in the National Report: *Engaged to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics* (2012, p.17). A district may want to select alternative active teaching strategies and alter the example to include strategies that are conducive to each district's STEM needs.

Figure 4.5 – Active Learning Strategies Professional Development: Planning Tool

Rate your knowledge of each active learning strategy on the following chart.

Active Learning Strategies	Never Heard of it	Minimal Knowledge	Basic/General Understanding	Solid Understanding	Mastery
Small group discussion and peer instruction					
One minute papers					
Clickers					
Problem-based learning					
Case Studies					
Analytical challenges before lecture					
Group Tests					
Problem sets in groups					
Concept mapping					
Writing with peer review					
Computer simulations and games					
One minute papers					

Figure – 4.5 illustrates the method an educational leader can use to obtain the active learning strategy information, they can decide which strategies the school may want to implement. The tool will help identify strengths and weakness and enable the professional development building-based team decide which strategies are the most appropriate for their environment. Teachers who are knowledgeable and skilled with a

particular strategy may lead a differentiated professional learning model focused on that strategy. The goal of active learning strategies is to enable a teaching staff to make connections between STEM barriers and the ways that effective instructional practices can reduce student barriers.

Is Developing Integrated STEM and Active Learning Strategies a Must-Solution Idea for a School District?

Developing integrated STEM and active learning strategies is not a “must” solution idea. Incorporating it into your initiative will depend upon teachers’ knowledge of active learning strategies and their willingness to work cooperatively to ensure that 21st century skills are embedded within each lesson. For our district, this multi-layered STEM solution idea held significant potential. There are four potential outcomes for Active Learning Strategies as a solution idea. The first aim was to enable teachers to implement instructional practices that increase students’ 21st century skills such as innovation, creativity, critical thinking, communication, and teamwork skills. A second outcome was to allow students to learn from real-world situations, to bring STEM fields alive, and to deepen student understanding. Third, through the use of active learning strategies, teachers became empowered to use strategies that engaged and motivated students. Finally, the aim was to expand K-12 STEM opportunities beyond the traditional classrooms through after-school programs, summer camps, science fairs, and clubs. Being exposed to STEM experts increases students’ self-efficacy and confidence as they relate to STEM education.

Connecting Active Learning Strategies to Integrated STEM

Developing 21st century skills for students is an additional outcome of educators utilizing active learning strategies. “Integrated STEM education calls for making connections across disciplines, so it is important to develop student and educator awareness of these connections and to leverage the connections in ways that improve learning” (Honey, 2014, p. 36).

Depending upon a school’s active learning strategy use and expertise, an educational leader could use the following administrative planning document to ensure that each 21st century skill is being integrated within every student’s schedule. For example, in a middle school with teams of teachers, each team of teachers should complete the document during a team planning period. Each subject area teacher would select at least one 21st century skill they plan to utilize during the designated nine-week period. This planning document is designed to be used four times during the school year, and the goal is to increase students’ STEM literacy by embedding 21st century skill across the curriculum. The figure below shows an example of the coordinated planning necessary among teams of teachers to ensure 21st century skills are embedded throughout a student’s schedule.

Figure 4.6 – 21st Century Skills Tracking Document

Team A: First Nine Weeks

Please indicate which 21st Century Skill you plan to utilize during the first nine weeks of school. Include a brief description of how you will utilize the skill and what you will consider as evidence that students have increased their ability to apply the skill to their thinking and their work.

21st Century Skills → Subject ↓	<i>Creativity</i>	<i>Critical Thinking</i>	<i>Communication</i>	<i>Innovation</i>	<i>Teamwork</i>
Science					
Math					
S.S.					
English					
Reading					
Languages					
Tech Ed					
Art					
Business					
Health					

Figure – 4.6 illustrates a tracking and planning document that teachers can use as a quick visual reference to determine if students have opportunities to apply and develop their 21st century skills across all subjects. This tracking document was developed for a middle school staff to monitor the type of 21st century skills they were providing to students each nine weeks. Through its use, teachers were able to increase their levels of communication across subjects and disciplines and to ascertain if each student had the opportunity to develop the necessary 21st century skills. Teachers should be encouraged to work on similar skills across disciplines. The aim of the tool is to ensure each 21st

century skill is being worked upon across all disciplines so that students might fully develop the skills necessary to achieve success when pursuing a STEM education.

Is a 21st Century Skills Teacher-Tracking System Necessary?

Without question, a 21st century skills teachers-tracking system is necessary. There are a variety of ways to build collaboration and communication between teachers besides this tracking tool, which is presented here as a practical example. Educational leaders may choose alternative methods to gather the same information therefore other tools may serve the same purpose.

Integrated STEM and active teaching strategy solution ideas have the potential to impact two of the STEM causes, USUR Student Barriers and Teacher Beliefs and Instructional Delivery, within the STEM driver diagram. Successful implementation of these solution ideas relies on a differentiated professional development, or PLC plan. For a STEM driver diagram for Active Student Learning Strategies, please refer to the Appendix G.

Chapter 5

Next Steps, Implications, and Conclusions

Chapter 5 provides educational leaders with the next steps, along with a professional development planning tool that can be utilized in selecting STEM solution ideas for their school. The tool was specifically designed and developed to help educational leaders determine their teachers' knowledge level of potential STEM solution ideas. Information gathered through this tool has the potential to help the leaders develop a professional development plan accommodate to the local STEM needs within a school district.

Now What? What Are the Next Steps an Educational Leader Should Take?

Educational leaders have various options for designing and implementing a district USUR student improvement plan. The first recommended action for the teachers and the educational leader is to develop increased knowledge of the barriers that prevent USUR students from pursuing a STEM education for the teachers and the educational leader. They should use the professional development planning barrier tool to establish baseline understanding to inform the design of a differentiated professional development plan to quickly increase both teacher and leader knowledge. Second, use the Theory of Profound Knowledge (Langley et al., 2009) to determine the most effective next step for your system, based on a solid understanding of the barriers and areas of strength in the system. Finally, determine which of the five STEM solution ideas presented within the

STEM Improvement Map and STEM Driver Diagrams are appropriate for your school system.

When educators within a school have an understanding of the USUR STEM barriers and the educational leader has knowledge of the five potential STEM solution ideas presented here, the improvement effort can begin. Educational leaders must then cooperatively work with their staff to develop their school's plan for increasing USUR student pursuit of a STEM education. The solution ideas presented here are not prescriptive, but are proscriptive, in that they should be selected and/or adapted to fit the needs of a particular school district, educational leader, or teaching faculty. In addition, the five solution ideas are presented as part of a multi-dimensional and multi-year improvement plan. Depending upon a school's needs, the solution ideas can be implemented by groups within the school or by individual teachers.

It is recommended that leaders start small and select the STEM solution idea that best fits the needs and strengths of the system and that has the best chance of success. Success will build followers and will inspire collaborative and active involvement with the professional development and implementation of a STEM improvement plan.

How to Select a STEM Solution Idea for your School System?

Let us assume the staff now has a solid understanding of the student barriers that prevent USUR students from entering and pursuing a STEM education. The STEM solution Figure – 5.1 below includes five STEM solution ideas that a district should consider when developing a STEM improvement effort. Accurately rate your knowledge

as an educational leader of each of the five solution ideas listed within the chart. Your responses will help you design a systematic and manageable improvement effort matched to your school system's needs. Teachers are asked to rate their knowledge of solution ideas, so that the length and depth of the overall plan can be adapted to the needs of the teaching staff. For example, if the entire staff's knowledge level was within the solid understanding or mastery levels within a particular solution idea (ex. Mindsets), that idea would be considered a strength and it would be appropriate to select another solution idea. It would be rare for all teachers to rank at the high end of understanding on any of the five ideas. More likely, the tool will help identify those teacher leaders who are knowledgeable within a solution idea. This professional development tool will allow educational leaders to select master teachers who are knowledgeable within a potential solution idea, and these master teachers will be part of the leadership team that would help to develop and define the STEM solution idea to fit the local school's STEM needs. In using this assessment tool, one must consider how well teachers can define each solution ideas.

Figure 5.1 – Professional Development: STEM Solution Planning Tool

Rate your knowledge of each STEM solution idea on the following chart. For those that you feel you have mastered or have a solid-to-basic understanding, include a brief description of your understanding.

STEM Solution Ideas	Never Heard of it	Minimal Knowledge	Basic/General Understanding	Solid Understanding	Mastery
Mindsets: Growth vs. Fixed					
Active Learning Strategies					
Productive Persistence					
Student Feedback that Promotes Student Resiliency Towards Learning (Formative Assessment)					
Integrated 21 st century skills					

STEM Roadmap Conclusion

The overall aim of this STEM roadmap is to provide the educational leader with the necessary tools to successfully design and develop a locally relevant STEM improvement plan for USUR students who have an interest in pursuing STEM education. The STEM Education Roadmap, Improvement Map, and Driver Diagram are Improvement Science tools that have helped educational leaders test ideas prior to implementation, making the change idea more effective. This STEM roadmap can serve

as a guide to get each district moving toward STEM solutions, but the destination of a district's STEM improvement plan will ultimately be determined by the teachers, students, and leaders within your school system.

This comprehensive and collaborative plan includes educational leader planning tools and actual examples of STEM improvement efforts that have grown from practice. These guiding tools will help educational leaders with strategies for STEM thinking within their districts while engaging educational professionals in conversations about USUR student STEM barriers, instructional practices, STEM causes, and STEM solution ideas. Additionally, the tools within this roadmap will provide educational leaders strategies for collaborating with teachers as they learn about methods to engage and reduce student barriers to STEM. It will provide tools that will enable leaders to better select teacher leaders, connect STEM professionals to a classroom, provide your students with authentic 21st century learning opportunities across subject areas, and will develop student's resiliency towards learning. These tools are meant to increase collaboration so that all educators in the school can learn and grow together, as well as attract followers toward improvement efforts. Educators are reminded to start off small, and adapt improvement aims through learning more and growing professionally. Utilizing these adaptable tools will create valuable STEM opportunities for students and ultimately will engage others with a STEM Education Roadmap for Success.

Implications for My Practice

I will continue to use Improvement Science strategies within my school to create change ideas. The learning design cycles have served as excellent mechanisms to learn how to plan and to implement a potential change idea. Through this experience, I have developed an in-depth understanding and working knowledge of how teachers respond to change ideas and I will use this knowledge to adapt and to change the next cycle of STEM improvements.

When creating change, an educational leader must adapt their learning strategies based upon their teachers' professional knowledge. An educational leader who is actively engaged in professional dialogue with the staff will know when to push and when to let the teachers work out the problems. Demonstrating flexibility as a leader is a key component to a professional improvement plan because one size does not fit all. Those leaders who utilize Improvement Science techniques in their school or school system will experience greater success than those leaders who merely present the problem without any solution ideas to explore learning possibilities and outcomes.

Improvement Science is action research in practice and is a new and promising mindset for educators. Educators who learn and adapt their practices to the local needs and share their stories along the way so that others can learn, will have positive impacts on any improvement effort.

This action research is in its early stages of development and the overall results are difficult to determine because student data regarding career choices will not be known

for several years. School leaders may be able to look at the student course selection as a measureable factor once students select electives.

This overall STEM improvement effort action research suggests that rapid, small chunks of change ideas will provide educational leaders with new information for continued, multi-stepped, and multi-year improvement efforts. This action research is within the development stage, and educators are learning what STEM solution ideas are effective in reducing USUR student barriers to STEM. Through a sustained effort, improvement will continue. As additional ideas are tested and modified throughout each school year, this improvement effort will enhance USUR students' pursuit of a STEM education, directly impacting the number of future students who will become gainfully employed within American science, technology, engineering, and mathematic positions.

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Appendix A

STEM Education Roadmap:

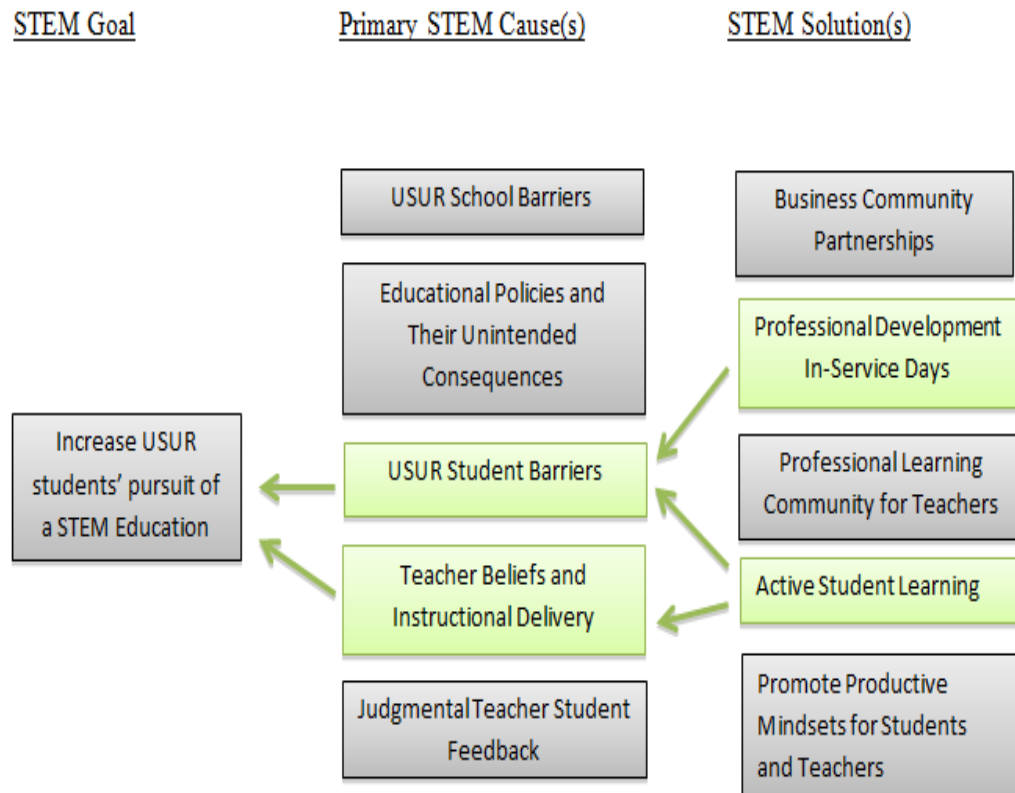
Seven Core Principles for Success

1. Utilize a Professional Learning Community which allows teachers to understand, recognize, and work to eliminate student barriers toward STEM education.
2. Develop student and teacher understanding about growth mindsets, providing students with the skills to productively persist when faced with challenging tasks.
3. Promote STEM instructional strategies and best practices that will inspire and motivate students through project-based learning, hands-on experiences, and formative assessments.
4. Enhance the quality of teacher-student feedback (formative assessment) to promote student resiliency towards learning.
5. Embrace and utilize instructional strategies that support the 21st century learner across all subject areas. These strategies will enhance students' innovation, creativity, critical thinking, communication, and teamwork skills.
6. Build local cooperative relationships between education and the business community to connect students with STEM-related experiences in and outside of school.
7. Provide educators with STEM learning opportunities at the school building level, along with education and training opportunities outside of the district to foster a Professional Learning Community.

Appendix B

Fantasy Baseball Driver Diagram

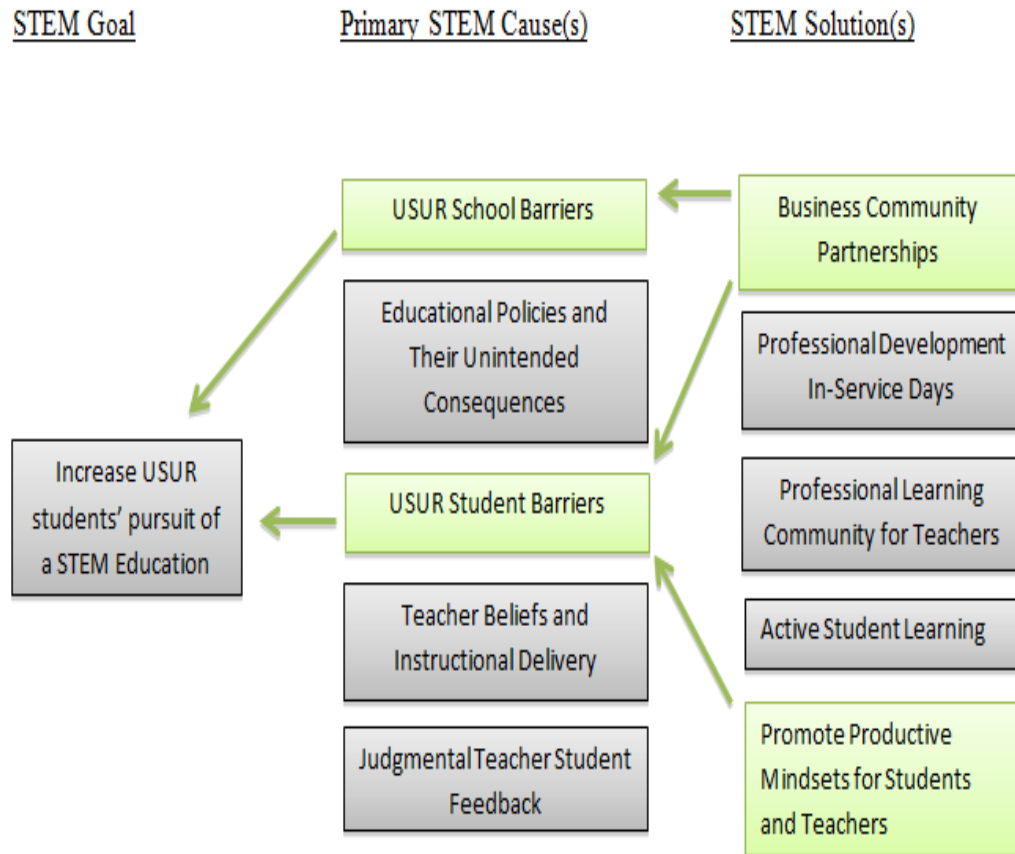
The boxes below are the causes and solution ideas associated with the Fantasy Baseball program. The intent here is to show how promoting professional development and active student learning leads towards achievement of the STEM goal.



Appendix C

Career Role Model Driver Diagram

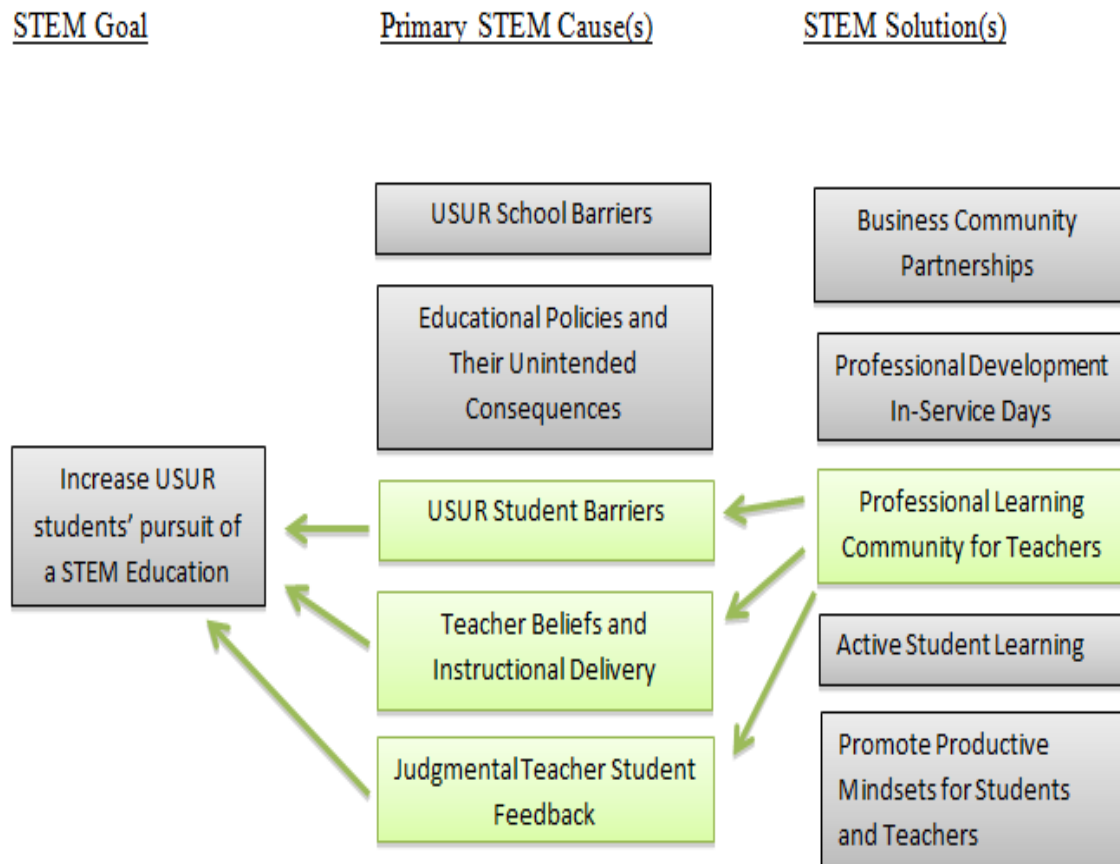
The boxes below are the causes and solution ideas associated with the Career Role Model or Career Storyteller program. The intent here is to show how promoting Business Community Partnerships and Productive Mind lead towards the achievement of the STEM goal.



Appendix D

STEM PLC Driver Diagram

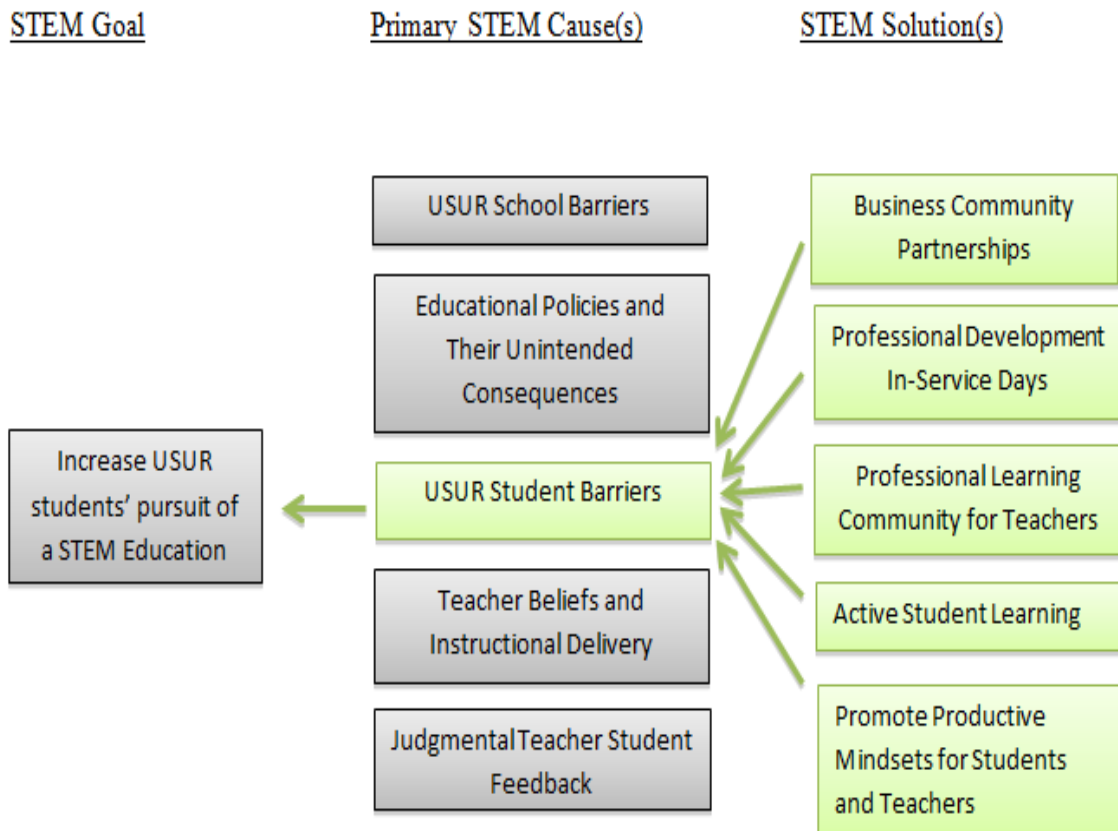
The boxes below are the causes associated with a PLC program solution idea. The intent here is to show how promoting professional learning communities leads toward achievement of the STEM goal.



Appendix E

STEM Solution Ideas Impacting USUR STEM Barriers

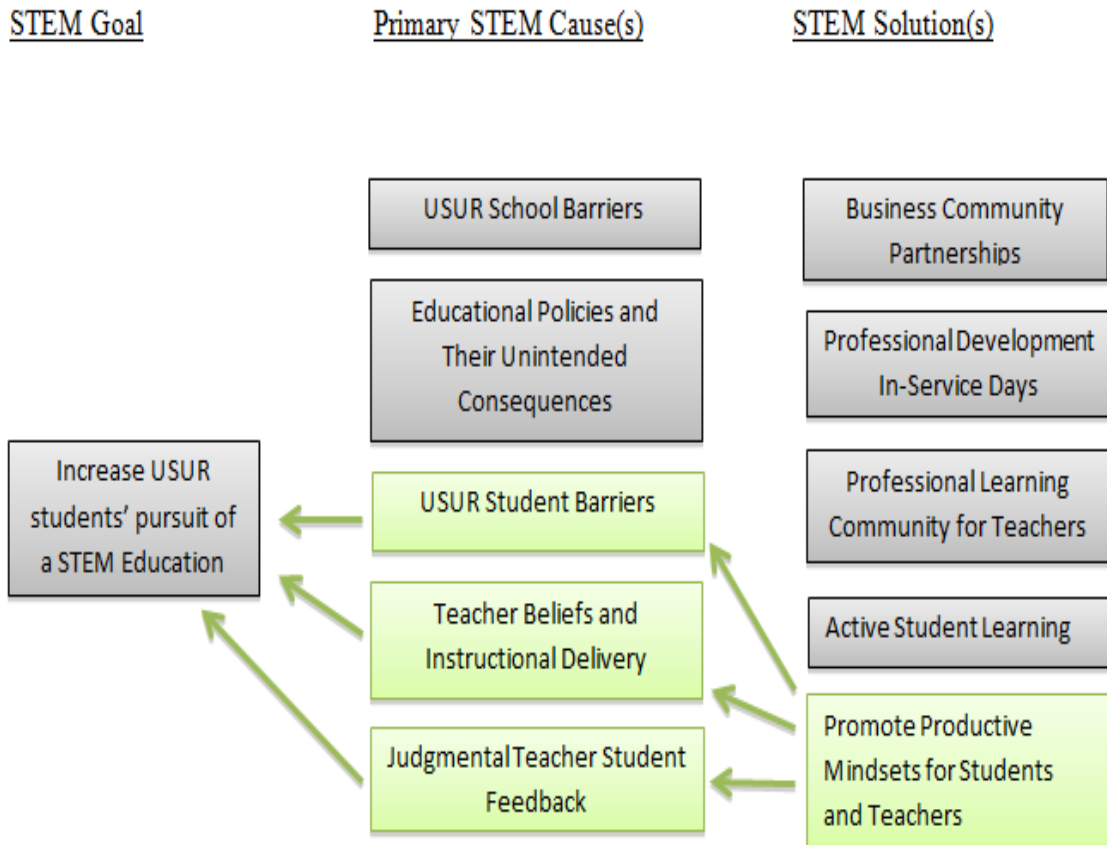
The boxes below are the solution ideas associated with the USUR Student Barriers. The intent here is for the educational leader to see how every solution idea is associated with USUR student barriers. Any one of the five solution ideas has the potential to achieve the desired STEM Goal.



Appendix F

Productive Mindsets Driver Diagram

The boxes below are the causes associated with the Productive Mindsets solution idea. The intent here is to show how promoting productive mindsets for students and teachers leads towards achievement of the STEM goal.



Appendix G

Active Student Learning Driver Diagram

The boxes below are the causes associated with the Active Student Learning solution idea. The intent here is to show how promoting active student learning leads toward achievement of the STEM goal.

